S
628.1
6832
H2sbcE4
1986

DRAFT

SILVER BOW CREEK

REMEDIAL INVESTIGATION FINAL REPORT

APPENDIX E, PART 4

STATE DOCUMENTS COLLECTION

FEB 9 1988

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

PLEASE RETURN

WATERFOWL INVESTIGATION

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

SUBMITTED TO:

Montana Department of Health and Environmental Sciences
Helena, Montana

PREPARED BY

Multitech

MONTANA STATE LIBRARY
S 628.16832 H2sbcE4 1986 c.1 Trout
Silver Bow Creek remedial investigation
3 0864 00059038 3

SEP 0 8 2009

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION
DRAFT FINAL REPORT

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

WATERFOWL INVESTIGATION

Author(s) and Contributors:

Robert Trout, Principal Investigator

Gordon Huddleston
Clarence Whitworth
Bob Sheehan
Sandra Fitch
Heather Johnson

Submitted To:

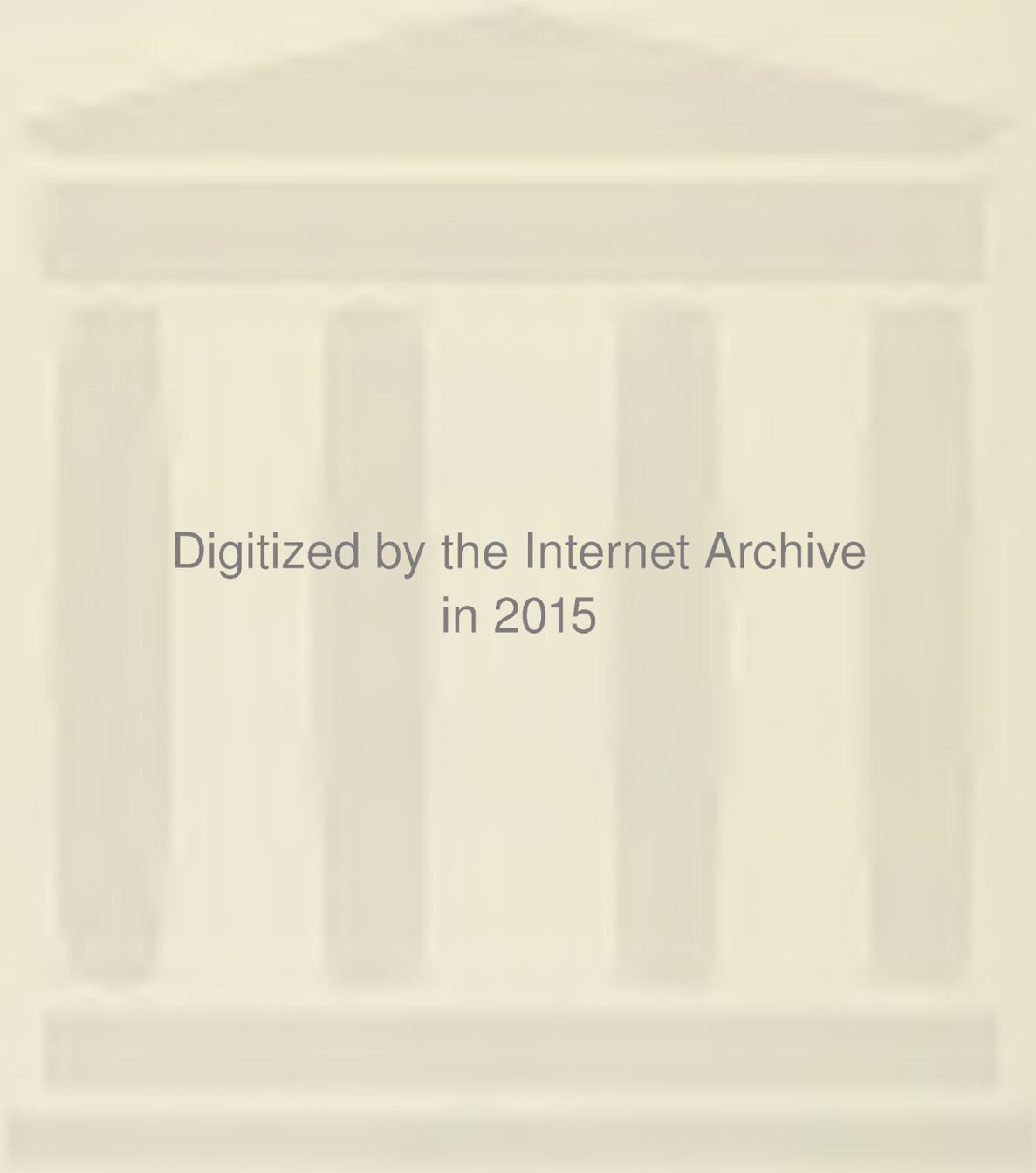
Solid and Hazardous Waste Bureau
Department of Health and Environmental Sciences
Cogswell Building
Helena, Montana 59620

Submitted By:

MultiTech
A Division of MSE, Inc.
P. O. Box 4078
Butte, Montana 59701

under contract No. 50341-1202503

MARCH 1986


Digitized by the Internet Archive
in 2015

https://archive.org/details/silverbowcreekr1986trou_1

PREFACE

Silver Bow Creek originates north of Butte, Montana and is a major tributary to the upper Clark Fork River. Mill tailings and other mining wastes in and near the creek contribute to substantial downstream contamination, particularly by potentially toxic elements: arsenic, cadmium, copper, lead, iron, and zinc. These elements and others were present in the mine ore and remain as by-products of the milling and smelting processes.

The history of mining in the Butte area began with the discovery of placer gold in Silver Bow Creek, in late summer of 1864. Several townsites and camps sprung up among the diggings. However, these operations were short-lived, and most of the miners left by 1869. Those who stayed began prospecting the quartz lode deposits of silver and the associated complex copper ores on the Butte Hill. Their efforts culminated in a silver rush, which began in the mid-1870's and revived the old camp. During that time world-class deposits of copper ore were identified. By 1881, Butte had become one of the nation's major mining centers; the district attained national dominance in copper mining by the mid-1890's and international prominence by the turn of the century. By 1915, Anaconda Copper Mining Company led the industry; but in 1980, in response to a depressed copper market, Anaconda closed all the underground mines and continued active mining only in the Berkeley Pit (established in 1955). In 1977, Anaconda became a subsidiary of Atlantic Richfield Company (ARCO). ARCO closed the Berkeley Pit in 1982 and the East Berkeley pit in 1983.

In addition to mining, various ore processing facilities also operated in the Butte area. The first two mills were erected in 1874 to smelt gold and silver. Ten years later, Marcus Daly, one of the founders of the Anaconda Company, built a copper smelter 27 miles west of Butte and planned the city of Anaconda. The Anaconda Smelter was moved to a new location in the city in 1900, and operated from 1903 to 1980.

The history of over 100 years of continuous mining and related activities changed the area's natural environment greatly. Early mining, milling, and smelting wastes were dumped directly into Silver Bow Creek and transported downstream to the Clark Fork River. In 1911, the first treatment pond was built by Anaconda Company near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water was allowed to move on. In 1916 and 1959, two more treatment ponds began operation. Silver Bow Creek continued to receive raw mining and milling wastes until 1972, when a treatment plant was added to the Weed Concentrator in Butte. Creek contamination problems were compounded by urban and domestic sewage, wood products treatment plants, phosphate and manganese production facilities, and chemical factories.

MultiTech

In 1983, the U.S. Environmental Protection Agency (USEPA) designated Silver Bow Creek, contiguous portions of the upper Clark Fork River, and their environs as a high priority Superfund clean-up site. The site extends from Butte to Deer Lodge, Montana, generally following the course of Silver Bow Creek and the upper Clark Fork River. Because the various mining activities interrupted the natural flow of Silver Bow Creek, the beginning of the creek for this investigation was established as the confluence of the Metro Storm Drain and Blacktail Creek, within the city limits of Butte. The site begins at the start of the Metro Storm Drain and ends at the Kohrs Bridge north of Deer Lodge.

The Silver Bow Creek Remedial Investigation (SBC RI) project consisted of coordinated individual studies to develop data on the extent and severity of contamination within the site. Results of the studies are reported in several volumes. A Summary Final Report discusses the entire project; final reports for each individual study have been issued as appendices to the Summary, as shown below:

- Surface Water and Point Source Investigation, Appendix A, Parts 1-3;
- Ground Water and Tailings Investigation, Appendix B, Parts 1-3;
- Warm Springs Ponds Investigation, Appendix C;
- Algae Investigation, Appendix D, Part 1;
- Vegetation Mapping, Appendix D, Part 2;
- Agriculture Investigation, Appendix D, Part 3;
- Macroinvertebrate Investigation, Appendix E, Part 1;
- Bioassay Investigation, Appendix E, Part 2;
- Fish Tissue Investigation, Appendix E, Part 3;
- Waterfowl Investigation, Appendix E, Part 4;
- Laboratory Quality Assurance/Quality Control Program, Appendix F, Part 1;
- Health and Safety Program, Appendix F, Part 2.

The Solid and Hazardous Waste Bureau (SHWB) of the Montana Department of Health and Environmental Sciences (MDHES) administered the USEPA appropriations to conduct this project. The Montana SHWB program manager was Mr. Michael Rubich. MDHES contracted with MultiTech in October 1984 to perform the SBC RI under contract No. 50341-1202503. The Project Manager at MultiTech was Mr. Gordon Huddleston.

MultiTech was assisted in the SBC RI work by Stiller and Associates of Helena and various other subcontractors. Several state and federal agencies also provided technical information and expertise, including the USEPA bioassay team, the Montana Department of Fish, Wildlife and Parks, the Montana Water Quality Bureau, and the USEPA Montana Field Office.

Information developed in the SBC RI will be used in the next phase of the project, the Feasibility Study, to evaluate options for site remediation.

EXECUTIVE SUMMARY

The principle objective of the Waterfowl Investigation was to provide data for an evaluation of human health risk in consuming waterfowl residing at the Warm Springs Treatment Ponds on the Silver Bow Creek (SBC) site. A secondary objective was to obtain data useful for an assessment of contaminant migration into biological systems. The actual evaluation of risk and assessment of contaminant migration will be addressed in the Public Health Assessment of the Feasibility Studies.

In this investigation a limited number of waterfowl from the Warm Springs Ponds were tested for metals (arsenic, cadmium, copper, and zinc) and organics (pentachlorophenol and polychlorinated biphenyls). Of the metals tested, cadmium was significantly elevated above background levels in waterfowl liver tissue, but not in muscle tissue. None of the remaining metals were found to be elevated above background levels in either muscle or liver tissue.

Measurable concentrations of pentachlorophenol (PCP) were found in the waterfowl tested, but a 22-lb child would have to consume 5.3 lbs/day of the worst-case tissue to reach the USEPA One-Day Health Advisory level of 1.0 mg/day or 1.6 lbs/day to reach the USEPA Ten-Day and Lifetime Health Advisory amount of 0.3 mg/day. Polychlorinated biphenyl (PCB) concentrations did exceed USDA food standards in some of the waterfowl tested, and circumstantial evidence indicates PCB contamination of biological organisms is occurring on the Silver Bow Creek CERCLA site. Specific sources of PCB contamination were not identified in this limited study.

MultiTech

TABLE OF CONTENTS

		Page
	PREFACE	i
	EXECUTIVE SUMMARY	iii
1.0	INTRODUCTION	1-1
	1.1 STUDY PLAN DEVELOPMENT AND OBJECTIVES	1-4
	1.1.1 Field Study Plan	1-5
	1.1.2 Objectives	1-6
	1.2 SITE INFORMATION	1-8
	1.3 HISTORICAL DATA	1-9
2.0	METHODS	2-1
	2.1 LOCATION OF SAMPLING SITES	2-1
	2.2 SAMPLE COLLECTION	2-1
	2.3 SAMPLE PREPARATION	2-6
	2.3.1 Sample Preparation For Metals Analysis	2-6
	2.3.2 Sample Preparation For PCP and PCB Analysis	2-8
	2.4 SAMPLE ANALYSIS	2-9
	2.4.1 Sample Analysis for Metals	2-9
	2.4.2 Sample Analysis for PCP and PCB	2-10
	2.5 DATA ANALYSIS	2-10
3.0	DATA ANALYSIS AND INTERPRETATION	3-1
	3.1 METALS DATA	3-1
	3.1.1 Quality Assurance and Quality Control Considerations	3-5
	3.1.2 Arsenic	3-8
	3.1.2.1 Arsenic Standards and Background Concentrations	3-8
	3.1.2.2 Statistical Tests of Arsenic Distribution in Waterfowl Tissues	3-11
	3.1.3 Cadmium	3-12
	3.1.3.1 Cadmium Standards and Background Concentrations	3-13
	3.1.3.2 Statistical Tests of Cadmium Distribution in Waterfowl Tissues	3-18
	3.1.4 Copper	3-20
	3.1.4.1 Copper Standards and Background Concentrations	3-20
	3.1.4.2 Statistical Tests of Copper Distribution in Waterfowl Tissue	3-22
	3.1.5 Zinc	3-23
	3.1.5.1 Zinc Standards and Background Concentrations	3-23
	3.1.5.2 Statistical Tests of Zinc Distribution in Waterfowl Tissue	3-24

TABLE OF CONTENTS (Continued)

		Page
3.2	ORGANIC DATA	3-25
3.2.1	Quality Assurance and Quality Control Considerations	3-28
3.2.2	PCP	3-28
3.2.2.1	PCP Standards and Background Concentrations	3-29
3.2.2.2	Statistical Tests of PCP Distribution in Waterfowl Tissues	3-31
3.2.3	PCB	3-32
3.2.3.1	PCB Standards and Background Concentrations	3-32
3.2.3.2	Statistical Tests of PCB Distribution in Waterfowl Tissues	3-37
4.0	CONCLUSIONS	4-1
4.1	METALS	4-1
4.1.1	Arsenic	4-1
4.1.2	Cadmium	4-2
4.1.3	Copper	4-3
4.1.4	Zinc	4-3
4.2	ORGANICS	4-4
4.2.1	PCP	4-4
4.2.2	PCB	4-4
REFERENCES		R-1
ATTACHMENT I	DESIGN CONSIDERATIONS	
ATTACHMENT II	QA/QC DATA	
ATTACHMENT III	LITERATURE EXAMPLES OF CONTAMINANT CONCENTRATIONS IN WATERFOWL TISSUE	
ATTACHMENT IV	STATISTICAL SUMMARIES	

LIST OF FIGURES

Page

1-1 HISTORIC CONTAMINATION OF SILVER BOW CREEK. 1-3

3-1 CADMIUM RESIDUES IN THE MUSCLE TISSUE OF MALLARD DUCKS FED CADMIUM. 3-16

3-2 CADMIUM RESIDUES IN THE LIVERS OF MALLARD DUCKS FED CADMIUM 3-17

LIST OF MAPS

1-1 SILVER BOW CREEK AND UPPER CLARK FORK RIVER 1-2

2-1 WARM SPRINGS PONDS 2-2

LIST OF TABLES

1-1 WATERFOWL INVESTIGATION PLAN 1-7

1-2 HISTORICAL DATA ON TRACE METAL LEVELS IN DUCK TISSUE . . . 1-10

2-1 SBC RI WATERFOWL SAMPLES 2-3

3-1 SBC RI WATERFOWL INVESTIGATION DATA. 3-2

3-2 MEANS, STANDARD ERRORS, AND RANGES FOR METALS IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO FOOD STANDARDS AND USDA BACKGROUND LEVELS 3-4

3-3 PCP AND PCB CONCENTRATIONS IN WARM SPRINGS PONDS AND ONE CONTROL WATERFOWL. 3-26

3-4 MEANS, STANDARD ERRORS, RANGES AND FOOD STANDARD COMPARISONS FOR PCP AND PCB IN WARM SPRINGS PONDS WATERFOWL. 3-27

3-5 PCP CONCENTRATIONS IN SURFACE WATER FOR SBC RI, 1984-1985. 3-30

3-6 SUMMARY OF PCB RESIDUES DETECTED IN TISSUES OF WATERFOWL IN MONTANA. 1981-1982, by MDFWP 3-34

1.0 INTRODUCTION

The objective of the Silver Bow Creek Remedial Investigation (SBC RI) is to determine the extent and severity of contamination within the Silver Bow Creek/Upper Clark Fork River system (See Map 1-1). Once the extent and severity of contamination within the site has been determined, the risk to humans can be assessed, and feasibility studies to develop remedial actions can be completed.

The Silver Bow Creek system has been contaminated by over 100 years of mining and smelting activities within the basin. Contaminants of concern are arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), and zinc (zn). These metals are found within the system at various concentrations, in various forms, and significantly above geochemical background levels. The major sources of these contaminants are tailings deposits and contaminated ground water (See SBC RI Surface Water and Ground-Water Reports, Appendices A and B). A timeline showing significant historical events that impacted Silver Bow Creek and the upper Clark Fork River is shown in Figure 1-1.

To evaluate potential risk, the migration of site contaminants into crops and animals consumed by humans needed to be determined during the RI. On the Silver Bow Creek site, three investigations were performed to allow this evaluation:

SILVER BOW CREEK

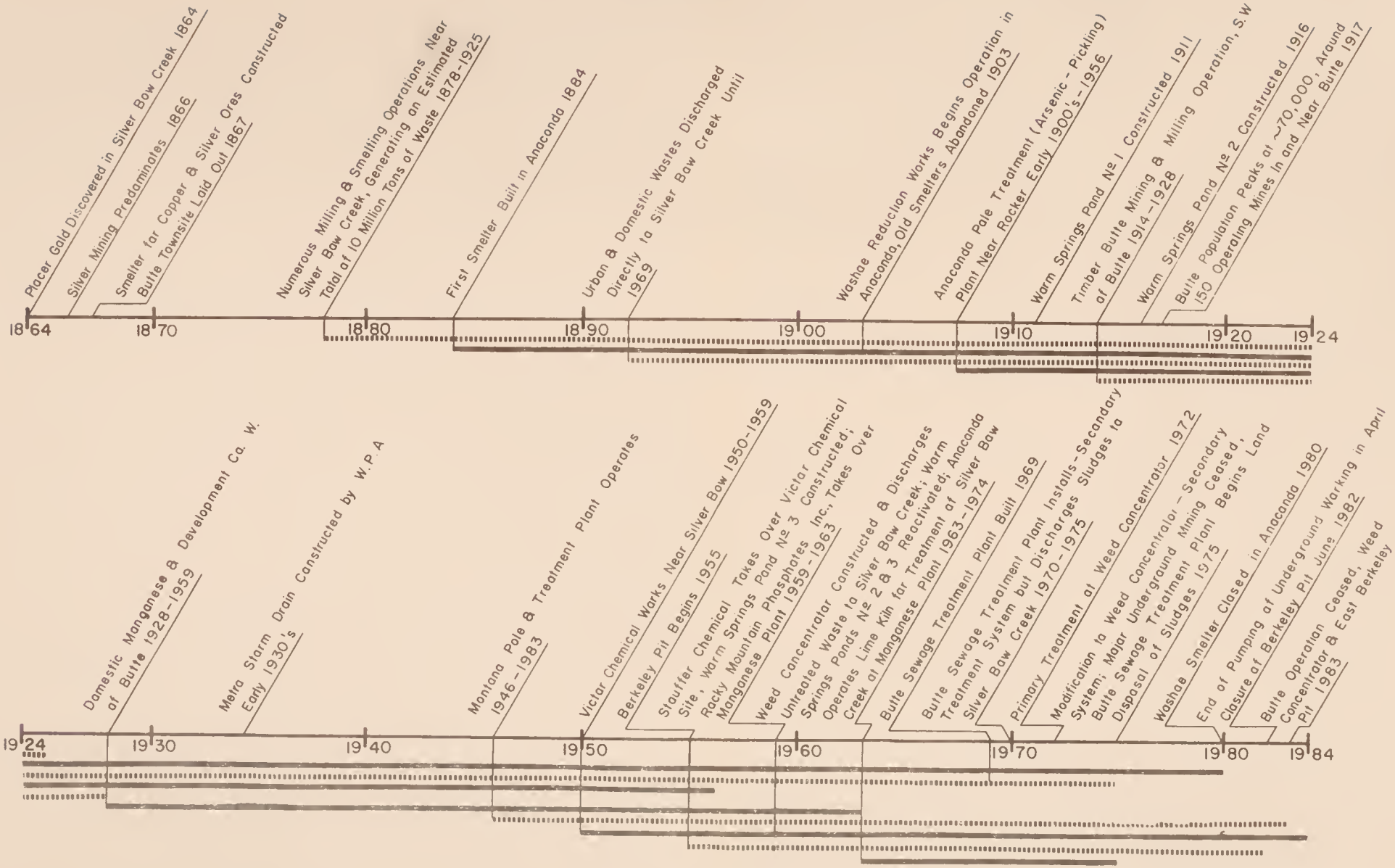
REMEDIAL INVESTIGATION

Map 1-1

Silver Bow Creek and
Upper Clark Fork River

FIGURE 1-1

HISTORICAL CONTAMINATION OF SILVER BOW CREEK


Placer Gold Discovered in Silver Bow Creek 1864
Silver Mining Predaminates 1866
Smelter for Copper & Silver Ores Constructed
Butte Townsite Laid Out 1867
Numerous Milling & Smelting Operations Near Silver Bow Creek, Generating an Estimated Total of 10 Million Tons of Waste 1878-1925
First Smelter Built in Anaconda 1884
Urban & Domestic Wastes Discharged Directly to Silver Bow Creek Until 1969
Washae Reduction Works Begins Operation in Anaconda, Old Smelters Abandoned 1903
Anaconda Pole Treatment (Arsenic - Pickling) Plant Near Rocker Early 1900's - 1956
Warm Springs Pond № 1 Constructed 1911
Timber Butte Mining & Milling Operation, S.W of Butte 1914-1928
Warm Springs Pond № 2 Constructed 1916
Butte Population Peaks at ~70,000, Around 150 Operating Mines in and Near Butte 1917
1864
1870
1880
1890
1900
1910
1920
1924
Domestic Manganese & Development Co. W. of Butte 1928-1959
Metra Storm Drain Constructed by W.P.A Early 1930's
Montana Pole & Treatment Plant Operates 1946-1983
Victor Chemical Works Near Silver Bow 1950-1959
Berkeley Pit Begins 1955
Stauffer Chemical Takes Over Victor Chemical Site, Warm Springs Pond № 3 Constructed; Rocky Mountain Phosphates Inc., Takes Over Manganese Plant 1959-1963
Weed Concentrator Constructed & Discharges Untreated Waste to Silver Bow Creek; Warm Springs Ponds № 2 & 3 Reactivated; Anaconda Operates Lime Kiln for Treatment of Silver Bow Creek at Manganese Plant 1963-1974
Butte Sewage Treatment Plant Built 1969
Butte Sewage Treatment Plant Installs - Secondary Treatment System but Discharges Sludges to Silver Bow Creek 1970-1975
Primary Treatment at Weed Concentrator 1972
Modification to Weed Concentrator - Secondary System; Major Underground Mining Ceased, Butte Sewage Treatment Plant Begins Land Disposal of Sludges 1975
Washae Smelter Closed in Anaconda 1980
End of Pumping of Underground Working in April Closure of Berkeley Pit June 1982
Butte Operation Ceased, Weed Concentrator & East Berkeley Pit 1983
1924
1930
1940
1950
1960
1970
1980
1984

- SBC RI Agricultural Investigation.
- SBC RI Fish Tissue Investigation.
- SBC RI Waterfowl Investigation.

The actual evaluation of risk and assessment of contaminant migration will be addressed in the Public Health Assessment as part of the Feasibility Studies.

This report documents the findings of the Waterfowl Investigation. Design criteria for the Waterfowl Investigation were developed from the information shown in Attachment I.

1.1 STUDY PLAN DEVELOPMENT AND OBJECTIVES

The two major groups of potential contaminant receptors and transporters are big game (deer and elk) and waterfowl (ducks and geese). Because big game use of contaminated areas, and therefore, the number of animals potentially affected, are both limited, they were not selected for study.

However, the Warm Springs Ponds provide an important year-round waterfowl habit, specifically managed for waterfowl by the Montana Department of Fish, Wildlife and Parks (MDFWP). This area has been used for waste-water treatment from the mining and milling operations in the basin and has significant quantities of contaminants in the bottom sediments and water of the ponds (see SBC RI Surface-Water and Ground-Water Reports, Appendices A, B and C). For these

reasons, waterfowl from the Warm Springs Ponds were selected for assessing contaminant migration into the biota associated with the Silver Bow Creek site.

1.1.1 Field Study Plan

The data existing on waterfowl in the site were insufficient to determine the extent of contaminant transport into waterfowl consumed by people. To obtain the data needed to meet the objectives of the SBC RI, a field study of the metal content of Warm Springs Ponds' waterfowl tissue was recommended during the RI study planning stage (MultiTech and Stiller and Associates 1984a).

January was selected to obtain wintering birds; September to obtain juveniles; and November to obtain migrating birds. A single specie (Mallard) was selected to reduce heterogeneity in sampling. Twenty five individuals were recommended to increase the power of statistical tests. Age classes were selected, to make adult/juvenile comparisons and to obtain a sample set of individuals that had spent their complete life on the ponds. Steel shot was recommended for collection to allow for uncontaminated lead (Pb) analysis of the tissues. Breast muscle was selected for analysis, as this is the tissue most often consumed by people. Sample preparation and analysis methods were selected to allow a comparison of data with food standards.

The work plan was modified prior to implementation through consultation with the MDFWP. MDFWP had an ongoing sample collection program, and to conserve project resources, these samples were selected for use in the Waterfowl Investigation. This utilization impacted the dates of collection, the number of samples obtained, the method of collection (shotgun with lead shot), the age of each sample, and the chain of custody documentation. Table 1-1 shows the study as planned and subsequently implemented.

Further consultation with MDFWP resulted in the approval of the analysis of five liver tissues for metals and five muscle and five liver tissues for PCP and PCB. Muscle tissue was selected, as this is the tissue most often consumed by the people. Liver tissue was selected, as this request to change the scope of the Investigation occurred after the dissection of the birds and the liver was the tissue most likely to have comparable literature data. PCP was selected for analysis as Silver Bow Creek was known to receive waste oil containing PCP. PCB was selected as it is a potential contaminant from the Butte urban area.

1.1.2 Objectives

The Silver Bow Creek Remedial Investigation Waterfowl Study was designed to meet the following objectives:

- Primary - Provide data that can be used to assess the human risk of consuming Warm Springs Ponds waterfowl.

TABLE 1-1
WATERFOWL INVESTIGATION PLAN

Collection and Analysis Specifications	Planned	Implemented
Dates of Sampling	Jan., Sept., Nov.	Feb - March, July - September
Locations of Sampling	Warm Springs Ponds	Warm Springs Ponds
Species to be sampled	Mallard	Mixed
Number of Individuals of each species at each sampling period	25	Total = 41
Age	Adult, except in September, then juvenile	Mixed
Collection Method	Shotgun, steel shot	Shotgun, lead shot
Tissue for Analysis	Breast muscle	41 Breast, 5 liver
Tissue Preparation Method	Dissection followed by digestion	Dissection followed by digestion or extraction
Analytical Method	AAS or ICPAES as appropriate for required MDL	AAS, ICPAES, GC
Parameters to be Measured	As, Cd, Cu, Pb, Hg, Zn	As, Cd, Cu, Zn, PCP, PCB

- Secondary - Provide data that can be used to assess the migration of contaminants into the biota utilizing the site.

These objectives were selected by SBC RI contractors and MDHES as best meeting the needs of the CERCLA (Superfund) process.

1.2 SITE INFORMATION

The Warm Springs Ponds are leased by the MDFWP from Anaconda Minerals Company and are a designated Wildlife Management Area (WMA). Major emphasis of management for this area is waterfowl habitat enhancement. Waterfowl use of the area during the spring, summer, and fall is heavy, with some birds overwintering (Greene 1984). No records have been maintained, but Greene (1984) indicates that waterfowl use and production have increased within the last ten years.

The area is attractive to waterfowl because of its relatively shallow water, macrophytes, fish populations (for fish-eating waterfowl), and minor disturbance potential. In addition, MDFWP has made efforts to enhance the waterfowl habitat through planting small grain, closing a portion of the area to hunting, and creating nesting habitat through island construction.

Diving ducks and puddleducks have been observed to utilize the ponds: canada goose (Branta canadensis), snow goose, (Chen caerule-

scens), mallard (Anas platyrhynchos), pintail (Anas acuta), gadwall (Anas strebera), green-winged teal (Anas carolineusis), blue-winged teal (Anas discors), cinnamon teal (Anas cyanoptera), American widgeon (Mareco americana), shoveler (Spatula clypeata), wood duck (Aix sponsa), Red head (Aythya americana), ring-necked duck (Aythya collaris), canvasback (Aythya valisineria), scaup (Aythya marila and A. affinis), common goldeneye (Bucephala clangula), Barrows goldeneye (Brucephalia islandica), Bufflehead (Brucephala albeola), ruddy duck (Oxyura jamaicensis), hooded merganser (Lophodytes cucullatus), common merganser (Mergus merganser), red-breasted merganser (Mergus serrator), common loon (Gavia immer), Rednecked grebe (Podiceps grisegena), horned grebe (Podiceps auritus), eared grebe (Podiceps nigricollis), western grebe (Aechmophorus occidentallis), and the pied-billed grebe (Podilymbus podiceps) (Trout 1983; Stoecker 1984; Skarr 1980). Shorebirds such as sandpipers, coots, avocets, and cranes also utilize this area (Trout 1983; Stoecker 1984; Skarr 1985).

1.3 HISTORICAL DATA

The only previous tissue concentration data on waterfowl from the Warm Springs Ponds for the contaminants of interest was collected in 1971. Results from that investigation, along with data from tissue analysis from ducks taken at different places or times in Montana, are shown in Table 1-2. The data shown in Table 1-2 are not sufficient to determine (1) whether these levels are elevated above background due to the ducks accumulating these levels from

TABLE 1-2
HISTORICAL DATA ON TRACE METAL LEVELS IN DUCK TISSUE

Species	Location	Kidney ppm			Liver ppm			
		Cd	Pb	Zn	As	Cd	Pb	Zn
Mallard	Warm Springs Ponds[a]				0	1.7	10-16	50
Mallard	Warm Springs Ponds[a]				0	12	10-16	110
Mallard	Great Falls[a]				0	.44	16-24	320
Mallard	Great Falls[a]				0	.44	16-24	70
Mallard A	Giant Springs[b]	1.08	4.3	117		.50	10.9	376
Mallard 1	Giant Springs[b]	1.72	6.9	147		.36	21.1	306
Mallard 2	Giant Springs[b]	.44	5.7	153		.10	26	301
Mallard 3	Giant Springs[b]	4.1	26.9	125		.24	22.0	124
Mallard 4	Giant Springs[b]	8.5	20.5	136		.74	15.1	288
Mallard	Unknown Control[b]	.42	0	19.8		.14	0	72.8

[a]Source: Hooper 1971.

[b]Source: Champa 1965.

their habitat, or (2) whether these levels would indicate a health hazard to humans consuming the ducks (metals tend to accumulate in kidney and liver tissue) (USEPA 1981).

Shambaugh (1983) studied the trace metal accumulation within the food chain at the Warm Springs Ponds. He determined that his data was insufficient for conclusions, but that they indicated the possibility of bioaccumulation by the aquatic biota inhabiting the ponds. If bioaccumulation is occurring in the aquatic biota, then waterfowl utilizing this biota for food may be exposed to elevated levels of contaminants.

Neher and Weisel (1977) examined the effects of heavy metal accumulation and its effects on the organisms of Warm Springs Ponds. However, they did not examine waterfowl tissue.

Waterfowl use of the upper Clark Fork River is year-round, with major migration peaks occurring in the fall and early spring. Production of ducks and geese occurs in this section of river, but no records are available. No tissue analysis of ducks from this area have been performed (Greene 1984). Species occurrence here is probably similar to that found on the Warm Springs Ponds.

2.0 METHODS

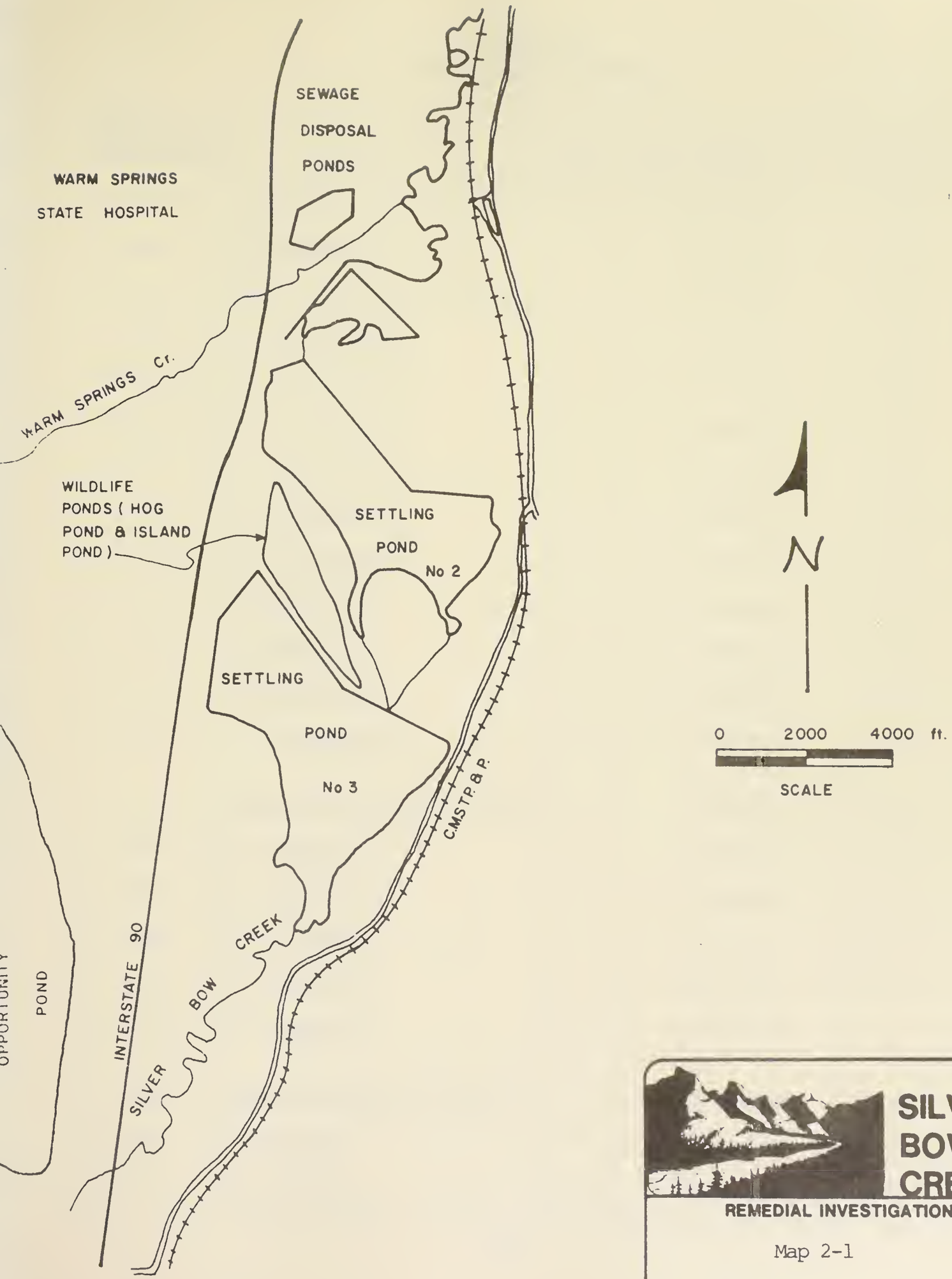
2.1 LOCATION OF SAMPLING SITES

Waterfowl occur throughout the SBC RI Study area (MultiTech and Stiller and Associates 1984a). The Warm Springs Ponds, located adjacent to Interstate 90 at Warm Springs, Montana (See Map 2-1) were selected as the site for sample collection because of their large, year-round waterfowl populations, and because metal contaminants of interest are known to concentrate in the bottom sediments. Control samples were collected off-site: three near Dillon, Montana and one near Three Forks, Montana. Total number of samples taken was 41.

2.2 SAMPLE COLLECTION

Waterfowl were taken by personnel of the Montana Department of Fish, Wildlife, and Parks (MDFWP) using shotgun loaded with lead shot. Warm Springs Ponds waterfowl were wrapped in freezer paper, taped, labeled with the date and location of collection, and placed in a freezer at the facilities of the Warm Springs Wildlife Management Area. Control waterfowl were wrapped in freezer paper, taped, labeled, and placed in the collector's home freezer until they could be transferred to the freezer at the Warm Springs Wildlife Management Area.

Sampling dates, number of samples taken, age, sex, and species of samples are presented in Table 2-1. Samples were transferred from



SILVER BOW CREEK

REMEDIAL INVESTIGATION

Map 2-1

Warm Springs Ponds

TABLE 2-1
SBC RI WATERFOWL SAMPLES

Date of Collection	Species	Age	Sex	Subfamily	Lab No.
2-29-84	*Brucephala sp.* (Goldeneye)	A	M	Aythyinae	T001
2-29-84	*Brucephala sp.*	A	F	Aythyinae	T002
3-01-84	*Anas platyrhnchos* (Mallard)	A	F	Anatinae	T003
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T004
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T005
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T006
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T007
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T008
3-01-84	*A. platyrhnchos*	A	M	Anatinae	T009
3-01-84	*Brucephala sp.*	A	M	Aythyinae	T010
3-01-84	*Brucephala sp.*	A	M	Aythyinae	T011
3-01-84	*Brucephala sp.*	A	M	Aythyinae	T012
3-02-84	*A. platyrhnchos*	A	M	Anatinae	T013
7-12-84	*Branta canadensis* (C. Goose)	J	-	Anserinae	T014
7-12-84	*B. canadensis*	J	-	Anserinae	T015
7-12-84	*B. canadensis*	J	-	Anserinae	T016
7-12-84	*B. canadensis*	J	-	Anserinae	T017
7-12-84	*B. canadensis*	J	-	Anserinae	T018
7-12-84	*B. canadensis*	J	-	Anserinae	T019
8-21-84	*Aythya americana* (Redhead)	J	-	Aythyinae	T020
8-21-84	*A. americana*	J	-	Aythyinae	T021
8-21-84	*A. americana*	J	-	Aythyinae	T022

TABLE 2-1
SBC RI WATERFOWL SAMPLES (Continued)

Date of Collection	Species	Age	Sex	Subfamily	Lab No.
8-21-84	A. americana	J	-	Aythyinae	T023
8-21-84	Anas platyrhnchos	J	-	Anatinae	T024
8-21-84	Aythya americana	J	-	Aythyinae	T025
8-21-84	Oxyura jamaicensis (Ruddy)	J	-	Oxyurinae	T026
8-21-84	Anas platyrhnchnos	J	-	Anatinae	T027
8-21-84	Aythya sp. (Scaup)	J	-	Aythyinae	T028
8-21-84	Aythya americana	J	-	Aythyinae	T029
8-21-84	Anas strepera (Gadwall)	J	-	Anatinae	T030
8-21-84	A. strepera	J	-	Anatinae	T031
8-21-84	Oxyura jamaicensis	J	-	Oxyurinae	T032
8-21-84	O. jamaicensis	J	-	Oxyurinae	T033
8-21-84	Aythya sp.	J	-	Aythyinae	T034
8-21-84	Aythya sp.	J	-	Aythyinae	T035
9-09-84	Anas discors (B.w. teal)	J	-	Anatinae	T036
9-09-84	Anas platyrhnchos	J	-	Anatinae	T037
9-10-84	A. platyrhnchos	J	-	Anatinae	T038
9-12-84	A. platyrhnchos	J	-	Anatinae	T039
9-12-84	Fulica americana (Coot)	-	-	Rallidae	T040
9-12-84	Anas platyrhnchos	J	-	Anatinae	T041
12-08-84	A. platyrhnchos(N of Dillon)	A	-	Anatinae	T042
12-09-84	A. platyrnchos (N of Dillon)	A	-	Anatinae	T043
12-09-84	A. platyrnchos (N of Dillon)	A	-	Anatinae	T044
12-? -84	A. platyrnchos (E of Three Forks)	A	-	Anatinae	T045

the Warm Springs Wildlife Management Area to the MultiTech Lab by MDFWP personnel; the samples were logged in, assigned lab numbers, and placed into laboratory freezers in the sample bank area.

Deviations from the SBC RI work plan for the Waterfowl Investigation occurred during sample collection, as the samples were collected during the spring, summer, and fall of 1984 prior to the completion and approval of the Work Plan (MultiTech and Stiller and Associates 1984a). These deviations were as follows:

- Samples were wrapped in paper rather than placed in plastic bags;

- No chain-of-custody forms were completed by MDFWP personnel and formal chain-of-custody procedures were not followed, and;

- Lead shot rather than steel shot was used for sample collection.

The use of lead shot invalidated planned lead analyses; therefore, none were performed. Other deviations have no direct effect on the data produced.

2.3 SAMPLE PREPARATION

2.3.1 Sample Preparation For Metals Analysis

Samples initially were prepared according to the following protocol:

(1) Remove waterfowl from the laboratory freezer and partially thaw at room temperature in their paper wrappings.

(2) Unwrap carcass and weigh to the nearest gram.

(3) Clean labware - for each bird, before dissection:

  (a) Rinse plastic wash basin with tap water, wash with 10% nitric acid, and rinse with de-ionized water.

  (b) Wash Teflon®-coated instruments with Liquinox®, rinse with tap water, follow with 10% nitric acid, and finally with de-ionized water.

  (c) Wash metal instruments not coated with Teflon® with Liquinox® and rinse with de-ionized water. Do not use nitric acid on uncoated metal instruments.

(4) Place bird in plastic wash basin and open the body cavity of each bird with a mid-ventral cut using surgical scissors. Remove the breast muscle, liver, kidney, stomach, and heart tissues by scalpel; place each tissue in a labeled plastic Whirlpak® and store in laboratory freezer.

(5) Dispose of remaining carcass.

Dissected tissues were digested prior to metals analysis according to the following protocol:

(1) Remove tissue sample (muscle, liver, etc.) from the freezer, thaw partially, cut in half, and remove approximately 4-grams (wet weight) from the inside of one of the halves. Weigh to the nearest .01 gram. Place in an Erlenmeyer flask.

(2) Add 2 ml of concentrated H_2SO_4 and 3 ml of concentrated HNO_3 to the flask and heat (but do not boil) until HNO_3 is evaporated (as indicated by the presence of dense, white SO_3 vapor).

(3) Remove flask from the heat, and wash the sides with deionized water. Add 3 ml concentrated HNO_3 and 1 ml 30% H_2O_2 and reheat the flask (no boiling).

(4) While being heated, add 3 ml concentrated HNO_3 and 1 ml 30% H_2O_2 five times.

(5) Heat until nitric acid is removed, cool, and bring to 50 ml in a volumetric flask with deionized water.

The protocol used deviated from the sample-preparation protocol found in the SBC RI Work Plan in three aspects:

- Dissection occurred after freezing and partial thawing of the whole bird, rather than on the day of collection;

- Dissecting tools were not washed between tissues;

- Samples were not homogenized prior to digestion, but the whole section was placed in the acid solution.

The first deviation should have no effect on data validity, as the metals of interest in the tissues are not transportable while the tissues are frozen. Not washing the tools during dissection on a single bird should have no effect on data validity, as the only contaminant between tissues was the blood of the individual bird, which is homogeneous in nature and occurs in large quantities within each tissue. Homogenization of tissues was specified to facilitate digestion; experience showed that the samples could be digested without this step, and eliminating this step removed a potential point of contamination.

2.3.2 Sample Preparation For PCP and PCB Analysis

Analysis of waterfowl tissue for pentachlorophenol (PCP) and polychlorinated biphenyls (PCB) was added as a component of the waterfowl investigation after the samples had been collected and dissected. The tissues selected for PCP and PCB analysis were chosen from the tissues remaining in the freezer following the metals analysis preparation step; Steps 1-5 for metals analysis sample

preparation and Step 1 for tissue preparation are the same for the PCP and PCB samples.

Samples used for PCP and PCB analysis were selected randomly from the available tissues. PCP sample extraction was performed as described in Characterization of Hazardous Waste Sites, a Methods Manual, Volume 3 - Available Laboratory Analytical Methods: "Analysis of Biological tissue samples for Acid Extractable Organic Compounds by Methylene Chloride Extraction" (USEPA 1984). PCB sample extraction was performed as described in the same Manual, "Analysis of Biological Tissues for Pesticides/Polychlorinated Biphenyls" (USEPA 1984).

2.4 SAMPLE ANALYSIS

2.4.1 Sample Analysis for Metals

The digestion solutions resulting from sample preparation were analyzed for arsenic and cadmium by flameless atomic absorption technique. Arsenic was analyzed using a hydride-vapor generation technique as described by USEPA Method 206.3 (USEPA 1983). Cadmium was analyzed by furnace using EPA Method 213.2 (USEPA 1983). Copper and zinc were analyzed by ICP as described by USEPA Method 200.7 (USEPA 1983).

2.4.2 Sample Analysis for PCP and PCB

The acid extraction solution was analyzed for PCP by EPA Method 604 (USEPA 1982) and PCB by EPA Method 608 (USEPA 1982).

2.5 DATA ANALYSIS

NWA STATPAK Software, Version 3.1 (NWA 1984) was used for all statistical analyses. Data were evaluated three ways: (1) less than the detection limit reported at the detection limit, (2) less than the detection limit at half the detection limit, and (3) less than the detection limit at half the detection limit and all arsenic and cadmium concentrations transformed by (log x) (-1) and all copper and zinc concentrations transformed by the square root of x. Data were transformed to normalize the frequency distribution of the small data sets available for analysis. Transformed data were preferred for data evaluation, as discussed in the following sections. The three data sets were evaluated to document the effect of method detection limit (MDL) changes and normalization. Means were compared using the t-test, and $\leq$ 5% probability of erroneously rejecting the null hypothesis was used as the significance criterion.

DRAFT

3.0 DATA ANALYSIS AND INTERPRETATION

3.1 METALS DATA

Forty-eight (48) tissue samples were analyzed from 45 individual waterfowl: 39 muscle tissues from 41 Warm Springs waterfowl submitted by MDFWP (two juveniles did not have sufficient breast tissue for analysis), five liver tissues from five of the 41 Warm Springs Ponds waterfowl (selected at random), and four muscle tissues from control samples collected at separate geographic sites (three from near Dillon, and one from near Three Forks, Montana).

Each tissue sample was analyzed for arsenic (As), cadmium (Cd), copper (Cu), and zinc (Zn). These elements are known or suspected contaminants in the Silver Bow Creek/Clark Fork River drainage. Each was contained in the ore mined and processed in the area. Water quality data that document the extent of arsenic, cadmium, copper, and zinc in the Silver Bow Creek/Upper Clark Fork River are found in reports from the SBC RI Surface-Water and Point-Source Investigation and the Ground-Water and Tailings Investigation, Appendices A and B. Table 3-1 presents the metals concentrations, in muscle and liver tissues, and Table 3-2 summarizes the data by presenting means, standard errors, ranges for muscle tissue, and food standards for each metal.

TABLE 3-1

SBC RI WATERFOWL INVESTIGATION DATA

Date of Collection	Species	Age	Sex	Subfamily	Lab No.	Body WT (g)	As in muscle (µg/g)*	As in Liver (µg/g)*	Cd in Muscle (µg/g)*	Cd in Liver (µg/g)*	Zn in Muscle (µg/g)*	Zn in Liver (µg/g)*	Cu in Muscle (µg/g)*	Cu in Liver (µg/g)*
2-29-84	Brucephala sp. (Goldeneye)	A	M	Aythyinae	T001	1093	<0.040	<0.056	0.065	4.53	9.47	33.7	6.25	19.4
2-29-84	Brucephala sp.	A	F	Aythyinae	T002	780	<0.038	0.047	0.084	1.35	9.37	36.4	6.52	25.4
3-01-84	Anas platyrhnchos (Mallard)	A	F	Anatinae	T003	1045	<0.042	0.042	0.055	1.41	11.2	54.4	5.25	23.5
3-01-84	A. platyrhnchos	A	M	Anatinae	T004	1139	<0.043	0.109	<0.014	2.95	8.09	50.4	3.76	93.9
3-01-84	A. platyrhnchos	A	M	Anatinae	T005	1225	<0.039	0.078	<0.013	1.46	15.7	105	2.48	67.5
3-01-84	A. platyrhnchos	A	M	Anatinae	T006	1122	<0.042	NR	<0.014	NR	9.60	NR	12.4	NR
3-01-84	A. platyrhnchos	A	M	Anatinae	T007	1159	<0.035	NR	0.055	NR	15.6	NR	5.51	NR
3-01-84	A. platyrhnchos	A	M	Anatinae	T008	1340	0.063	NR	0.016	NR	9.08	NR	3.71	NR
3-01-84	A. platyrhnchos	A	M	Anatinae	T009	1244	<0.038	NR	0.014	NR	9.82	NR	4.31	NR
3-01-84	Brucephala sp.	A	M	Aythyinae	T010	944	<0.038	NR	0.100	NR	12.9	NR	7.67	NR
3-01-84	Brucephala sp.	A	M	Aythyinae	T011	1032	<0.040	NR	0.082	NR	11.3	NR	5.67	NR
3-01-84	Brucephala sp.	A	M	Aythyinae	T012	1050	<0.060	NR	0.026	NR	10.0	NR	4.86	NR
3-02-84	A. platyrhnchos	A	M	Anatinae	T013	1219	<0.059	NR	<0.014	NR	7.68	NR	4.19	NR
7-12-84	Branta canadensis (C. Goose)	J	-	Anserinae	T014	2015	<0.055	NR	0.064	NR	15.2	NR	2.14	NR
7-12-84	B. canadensis	J	-	Anserinae	T015	2728	0.080	NR	0.066	NR	14.1	NR	3.54	NR
7-12-84	B. canadensis	J	-	Anserinae	T016	1662	<0.060	NR	0.042	NR	13.5	NR	3.86	NR
7-12-84	B. canadensis	J	-	Anserinae	T017	2640	0.059	NR	0.244	NR	18.2	NR	6.13	NR
7-12-84	B. canadensis	J	-	Anserinae	T018	2794	<0.051	NR	<0.012	NR	15.2	NR	3.69	NR
7-12-84	B. canadensis	J	-	Anserinae	T019	1687	0.062	NR	<0.014	NR	10.7	NR	2.71	NR
8-21-84	Aythya americana (Redhead)	J	-	Aythyinae	T020	319	0.281	NR	0.658	NR	21.8	NR	5.61	NR
8-21-84	A. americana	J	-	Aythyinae	T021	447	<0.127	NR	0.081	NR	16.3	NR	4.44	NR
8-21-84	A. americana	J	-	Aythyinae	T022	419	<0.116	NR	0.133	NR	17.3	NR	4.74	NR

* wet weight basis
NR = Not Required.

TABLE 3-1

SBC RI WATERFOWL INVESTIGATION DATA (Continued)

Date of Collection	Species	Age	Sex	Subfamily	Lab No.	Body WT g	As in muscle µg/g*	As in Liver µg/g*	Cd in Muscle µg/g*	Cd in Liver µg/g*	Zn in Muscle µg/g*	Zn in Liver µg/g*	Cu in Muscle µg/g*	Cu in Liver µg/g*
8-21-84	A. americana	J	-	Aythyinae	T023	387	<0.290	NR	0.342	NR	16.7	NR	4.08	NR
8-21-84	Anas platyrhnchos	J	-	Anatinae	T024	697	0.135	NR	0.027	NR	10.6	NR	3.79	NR
8-21-84	Aythya americana	J	-	Aythyinae	T025	265	<0.366	NR	0.268	NR	15.1	NR	<3.10	NR
8-21-84	Oxyura jamaicensis (Ruddy)	J	-	Oxyurinae	T026	129	N.A.	NR	NP	NR	NP	NR	NP	NR
8-21-84	Anas platyrhnchos	J	-	Anatinae	T027	577	0.104	NR	0.016	NR	13.1	NR	2.60	NR
8-21-84	Aythya sp. (Scaup)	J	-	Aythyinae	T028	109	<1.27	NR	1.27	NR	22.4	NR	<10.8	NR
8-21-84	Aythya americana	J	-	Aythyinae	T029	797	<0.098	NR	0.054	NR	11.5	NR	5.84	NR
8-21-84	Anas strepera (Gadwall)	J	-	Anatinae	T030	267	<0.356	NR	0.311	NR	19.0	NR	3.83	NR
8-21-84	A. strepera	J	-	Anatinae	T031	243	<0.295	NR	0.168	NR	16.5	NR	5.45	NR
8-21-84	Oxyura jamaicensis	J	-	Oxyurinae	T032	116	N.A.	NR	NP	NR	NP	NR	NP	NR
8-21-84	O. jamaicensis	J	-	Oxyurinae	T033	--	<0.637	NR	<0.097	NR	14.3	NR	<5.40	NR
8-21-84	Aythya sp.	J	-	Aythyinae	T034	274	<0.564	NR	<0.086	NR	20.9	NR	8.57	NR
8-21-84	Aythya sp.	J	-	Aythyinae	T035	294	<0.556	NR	<0.085	NR	13.2	NR	<4.72	NR
9-09-84	Anas discors (B.w. teal)	J	-	Anatinae	T036	464	0.076	NR	<0.012	NR	11.0	NR	8.88	NR
9-09-84	Anas platyrhnchos	J	-	Anatinae	T037	979	0.069	NR	0.014	NR	8.77	NR	3.60	NR
9-10-84	A. platyrhnchos	J	-	Anatinae	T038	953	0.013	NR	0.039	NR	9.86	NR	3.92	NR
9-12-84	A. platyrhnchos	J	-	Anatinae	T039	837	<0.066	NR	<0.012	NR	11.3	NR	5.07	NR
9-12-84	Fulica americana (Coot)	-	-	Rallidae	T040	502	0.067	NR	<0.010	NR	16.5	NR	12.0	NR
9-12-84	Anas platyrhnchos	J	-	Anatinae	T041	886	0.123	NR	0.039	NR	10.9	NR	4.68	NR
12-08-84	A. platyrhnchos(N of Dillon)	A	-	Anatinae	T042	1163	<0.067	NR	0.167	NR	7.9	NR	4.03	NR
12-09-84	A. platyrnchos (N of Dillon)	A	-	Anatinae	T043	1214	<0.060	NR	0.120	NR	9.8	NR	3.88	NR
12-09-84	A. platyrnchos (N of Dillon)	A	-	Anatinae	T044	1280	<0.062	NR	<0.010	NR	15.1	NR	6.24	NR
12-? -84	A. platyrnchos (E of Three Forks)	A	-	Anatinae	T045	1278	<0.082	NR	<0.015	NR	10.8	NR	4.66	NR

* Wet weight basis
NR = Not Required.
NP = Not Performed, due to insufficient muscle tissue.

TABLE 3-2

MEANS, STANDARD ERRORS, AND RANGES FOR METALS IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO FOOD STANDARDS AND USDA BACKGROUND LEVELS. DATA ARE PRESENTED FOR <DL AT DL, <DL AT ONE HALF THE DL, <DL AT ZERO, AND <DL DELETED FROM THE DATA SET - DL = DETECTION LIMIT.

	No.	Mean[a]	SE[a]	Range[a]	Standard	Background[a&g]
Arsenic						
<DL deleted	12	0.103	0.018	0.059-0.281	0.70[a,c] 0.50[a,d]	no.=280
<DL at DL	37	0.161	0.038	<0.035-<1.27[b]		ND($\bar{x}$)
<DL at 1/2 DL	37	0.0963	0.020	<0.018-<0.64		0.15(max)
Cadmium						
<DL deleted	27	0.160	0.051	0.014-1.27	400-500 µg/week[e]	no.=280
<DL at DL	37	0.124	0.038	<0.01-1.27		ND($\bar{x}$)
<DL at 1/2 DL	37	0.121	0.038	<0.006-1.27		0.15(max)
Copper						
<DL deleted	34	4.99	0.352	2.14-12.4	100[a,f]	no.=280
<DL at DL	37	5.09	0.363	2.14-12.4		avg.3($\bar{x}$)
<DL at 1/2 DL	37	4.84	0.344	1.5-12.4		5 (max)
Zinc						
<DL deleted	37	13.3	0.645	7.68-22.4	100[a,f]	NG[h]
<DL at DL	37	13.3	0.645	7.68-22.4		
<DL at 1/2 DL	37	13.3	0.645	7.68-22.4		

(a) All values in µg/g wet weight.
(b) Max value <MDL of 1.27 for sample due to low weight of tissue available for digest.
(c) Maximum allowed by USDA/APHIS meat inspections in cattle (USDA No Date).
(d) Maximum allowed by USDA/APHIS meat inspections in swine (USDA No Date).
(e) Provisional tolerable weekly intake (FAO/WHO 1972).
(f) Canadian Food Directorate (Phillips 1982).
(g) Data for domestic ducks used by the USDA to evaluate for contamination in marketed domestic ducks. ND = Not detected. Detection limit estimated at 0.1 µg/g.
(h) NG = not given.

3.1.1 Quality Assurance and Quality Control Considerations

The Silver Bow Creek Remedial Investigation Quality Assurance and Quality Control Plan (SBC RI QA/QC Plan) (MultiTech and Stiller and Associates 1984b) and the SBC RI Work Plan were followed for the study except as previously noted in Section 2.0 regarding sample preparation. Attachment II contains QA/QC information for the Waterfowl Investigation.

The QA/QC Plan requires the following: (1) analysts' calibration checks, replicates, and spikes to be performed at a frequency of 10% and to be within specified control limits; (2) blind (sample bank) solution standards, digestion standards, digestion spikes, and digestate splits at a frequency of one in forty; and (3) blind (sample bank) digestion blanks and tissue splits at a frequency of one in twenty. QA/QC data is summarized in Attachment Tables II-1 through II-4.

Method Detection Limits (MDL = three times the standard deviation of replicate determinations of a calibration blank) were experimentally determined for each batch of analyses and are reported as determined, including corrections for variations in sample weight and final digestate volume. Samples for which relatively little tissue was available showed a concomitantly larger MDL. Juvenile waterfowl most often showed the large <MDL's, as their breast tissue was not yet developed and very little was available for digestion.

The data of Attachment Tables II-1 through II-4 indicate the accuracy and precision of the sample preparation and analysis. Analysts' replicates, calibration checks, and spikes indicate the accuracy and precision of post-digestion steps in the analysis. Sample bank standards, spikes, blanks, and duplicates indicate the cumulative accuracy and precision of the post-digestion steps and all other steps included in the preparation of the particular sample bank sample.

Review of these data shows that the precision and accuracy of the analysis at the instrument was good, with the duplicate sample agreement/replicate sample agreement (DSA%/RSA%), known sample agreement (KSA%), and spike sample recovery (SSR%) values well within the limits set by the SBC RI QA/QC plan.

Sample bank samples also indicated very good precision and accurancy as measured by recoveries for pre-and post-digestion standards, duplicates, and spikes, with the following exceptions:

- Arsenic levels in NBS Bovine Liver 1577 (the sample bank standard) were below the MDL and were not used to evaluate arsenic precision or accuracy of arsenic analysis or recovery. Analysts' standards, duplicates, and spikes gave good recoveries, as did sample bank post-digestion standards and pre-digestion spikes, indicating acceptable accuracy and precision in recovery of arsenic in the digestion process.

- Cadmium recoveries in two sample bank pre-digestion standards (NBS Bovine Liver 1577) and one sample bank tissue split were less than 35%. These samples were re-analyzed and the new KSA% values for NBS Bovine Liver 1577 were 73 and 93%, respectively. Other sample bank samples re-analyzed with the NBS standards showed good agreement with the first analysis run. These data are presented in Attachment Table II-2.

Q361 and Q362, both NBS Bovine Liver 1577, were weighed for digestion dry. This means that these two samples were effectively more concentrated than the wet experimental samples. However, Q361 and Q362 were digested in exactly the same manner as the wet samples, which may have led to incomplete digestion, resulting in low recovery data. The second analysis run of Q361 and Q362, which showed an apparent improvement in recoveries, may be showing that more cadmium went into solution with time for these two samples. Assuming this is the appropriate explanation for the QA/QC data, cadmium recoveries in the experimental samples appear adequate.

The sample bank tissue split re-analysis shows a DSA of 48%. This low DSA% confirms the original measurements and indicates heterogeneity in the tissues analyzed.

3.1.2 Arsenic

The toxicity of arsenic is well known, with arsenic concentrations regulated in public drinking water supplies (40 CFR 141) and food stuffs (Spaulding 1985). Because the ores in the upper Silver Bow Creek drainage are known to have contained arsenic and the waste material deposited within the Silver Bow Creek (SBC) drainage came from these ores, arsenic was suspected as a contaminant within the SBC system.

3.1.2.1 Arsenic Standards and Background Concentrations

Table 3-2 lists the meat and poultry standards for arsenic promulgated by the USDA (No Date). A comparison of the arsenic concentration data in Tables 3-1 and 3-2 shows that none of the measured values exceeded the standards. Several of the juvenile samples, including T021, T022, T023, T025, T028, T030, T031, T033, T034, and T035 showed detection limits near or above the standards. These detection limits were a function of the mass of the tissue used, which for these samples was the total that was available. For those samples for which real values were calculated, the value was never more than 56% of the standard of 0.50 ppm.

The USDA also uses national averages of residue concentrations for comparisons (Spaulding 1985). The USDA comparison for arsenic in domestic waterfowl muscle is presented in Table 3-2. Comparing the data in Table 3-1 to the USDA data in Table 3-2 reveals that only

T020 and T024 had muscle concentrations of arsenic above the "high" of 0.15 µg/g. Of those juvenile samples for which adequate amounts of tissue were available for analysis, none were found to have muscle tissue concentrations above 0.15 µg/g.

A statistical comparison of these data sets was not possible, as the variation in the USDA sample was unknown. However, the arsenic concentrations in Warm Springs Ponds waterfowl muscle tissue do not appear elevated above concentrations found in domestic waterfowl meant for human consumption.

In 280 domestic waterfowl liver samples the USDA found less than 0.1 µg/g arsenic on the average, with the maximum liver sample at 0.20 µg/g (Spaulding 1985). None of the five liver tissues analyzed showed arsenic concentations above 0.109 µg/g. Even though this small data set allows no statistical comparison and the USDA data set variation was unknown, Warm Springs Ponds waterfowl liver tissue arsenic concentrations do not appear elevated above arsenic concentrations found in the livers of domestic waterfowl meant for human consumption.

These conclusions regarding arsenic in Warm Springs Ponds waterfowl tissue must be evaluated in light of the QA/QC data. The MDL was above the arsenic concentration in the NBS Standard, which prevented the calculation of KSA%'s (KSA% is defined in Attachment Table II-1) for the complete method. However, the SSR% (SSR% is defined in

Attachment Table II-1) for the sample bank spikes showed acceptable values of 88-109%, indicating good arsenic recovery.

Table III-1 in Attachment III (Literature Examples of Contaminant Concentrations in Waterfowl Tissue) presents two examples of arsenic in waterfowl tissue. Ambient arsenic concentrations are given in this table, if known. Turner et. al. (1978) studied metal content in the livers of several species of water birds in New Zealand. Compared with the mean liver concentration of arsenic in Warm Springs Ponds waterfowl of 0.069 µg/g (n=4, SD=0.031), Turner's values appear much higher. However, given the small sample size of this study, little can be said for the significance of the differences. Greichus et al. (1978) studied arsenic content of carcasses of a species of comorant in Rhodesia. His study was more limited in samples than the Silver Bow Creek study, but he calculated an average arsenic concentration of 1.4 µg/g (dry weight) which would approximately equal 0.35 µg/g wet weight (assuming body = 75% water). This value is higher than the average values obtained for arsenic in Warm Springs Ponds waterfowl muscle of 0.018 (<DL deleted) or 0.038 (<DL at DL).

These data suggest that arsenic is not at elevated levels in Warm Springs Ponds waterfowl.

3.1.2.2 Statistical Tests of Arsenic Distribution in Waterfowl Tissues

Average arsenic concentrations in muscle and liver tissue of Warm Springs Ponds waterfowl were compared. Age, sex, subfamily, and control versus Warm Springs Ponds comparisons were performed for muscle tissue averages only.

Attachment IV contains statistical summaries for the SBC RI Waterfowl. Table IV-1 compares arsenic concentrations in muscle tissues of Warm Springs Ponds waterfowl to the control samples. Table IV-2 compares muscle tissue and liver tissue arsenic concentrations from Warm Springs Ponds waterfowl. Tables IV-3, IV-4, and IV-5 compare Warm Springs Ponds waterfowl muscle tissue arsenic concentrations by age, sex, and subfamily, respectively.

Using a 5% probability of erroneously rejecting the null hypothesis (H_O = No difference in the means) as the significance criterion, the only significant differences found in the age, sex, and subfamily comparisons were as follows:

- A significant difference in arsenic concentrations was found between the age classifications.
- Males and females had calculated, significantly lower average muscle arsenic concentrations than did those waterfowl of undetermined sex. (Female significance occurred only in the transformed data set).

The significant differences between males and females versus those of unknown sex and between adults and juveniles may be attributable to the high MDL values calculated for many of the juvenile samples which did not have their sex determined. These high MDL values probably erroneously bias the mean.

Table IV-6 presents the coefficients of determination (r^2) for the following: arsenic concentrations in liver versus body weights; arsenic concentrations in muscle versus body weight; arsenic concentrations in muscle versus cadmium, copper, and zinc concentrations in muscle; and arsenic concentrations in liver versus cadmium, copper, and zinc concentrations in liver. Only arsenic and copper in liver appeared to be correlated.

3.1.3 Cadmium

Cadmium was a suspected contaminant in the Silver Bow Creek/Upper Clark Fork River system because it occurred in the ores processed in the upper part of the drainage system. Cadmium is regulated in public drinking water supplies (40 CFR 141), but it is not regulated in food in the United States (USDA No Date and Spaulding 1985). Measurable cadmium concentrations were found in both surface-water and ground-water samples collected as part of the SBC RI.

3.1.3.1 Cadmium Standards and Background Concentrations

FAO/WHO (1972) has promulgated 400-500 µg/week cadmium as the PTWI (provisional tolerable weekly intake). To exceed this standard, a person would have to consume 13.7 oz. of the Warm Springs Ponds worst-case waterfowl muscle tissue (1.27 µg/g) in one week. However, using the average Warm Springs Ponds Waterfowl concentration of 0.16 µg/g cadmium (for samples with detectable amounts), a person would have to eat 116 oz. (7.3 lbs.) of duck muscle a week to exceed the standard.

The USDA national average for cadmium residues in the muscle of domestic ducks is presented in Table 3-2. Comparing the cadmium concentrations in Warm Springs Ponds waterfowl muscle tissue to the national "high" of 0.15 µg/g reveals that eight Warm Springs Ponds samples had cadmium concentrations above the "high": TO17 at 0.244 µg/g; TO20 at 0.658 µg/g; TO23 at 0.342 µg/g; TO25 at 0.268 µg/g; TO28 at 1.27 µg/g; TO30 at 0.311 µg/g; TO31 at 0.168 µg/g; and TO42 at 0.167 µg/g (a control sample). The overall average of cadmium concentrations in muscle tissue of the samples was calculated at 0.124 µg/g for less than the MDL reported at the MDL; 0.121 µg/g for less than the MDL reported at half the MDL; and 0.160 for <DL deleted. These data indicate that cadmium concentration in Warm Springs Ponds waterfowl muscle tissue may be above the national norm for domestic waterfowl.

The cadmium concentrations in the livers of the Warm Springs Ponds waterfowl are much higher than the USDA national average of .2 µg/g or the USDA "high" of 0.4 µg/g for domestic waterfowl (Spaulding 1985). The ducks selected for liver tissue analysis were collected in late February and early March of 1984. These ducks were assumed to have wintered on the ponds and may represent the longest potential exposure to the contaminants. The values for cadmium in their liver tissues were 4.53, 1.35, 1.41, 2.95, and 1.46 µg/g, 7-22 times the USDA domestic waterfowl national average and 3-11 times the USDA domestic waterfowl national "high". Cadmium is known to concentrate in the liver and kidneys of animals, as these are the organs responsible for removing toxins (Leach, et al. 1979). The Warm Springs Ponds samples for which livers were tested show this pattern of tissue concentration.

Cadmium has been measured more frequently than arsenic in waterfowl tissue, as shown in the examples from the literature in Attachment Table III-2. Ambient cadmium concentrations are presented in this table, if known. The Warm Springs Ponds waterfowl average cadmium concentrations in muscle (0.160-0.124 µg/g) are greater that Maedgen, et al. (1982) showed for Royal tern muscle (0.017-0.075 µg/g) in Galveston Bay, Texas and Greichus, et al. (1978) showed for white-breasted cormorants from Lake McIlwaine, Rhodesia ($\bar{x}$=0.04 µg/g); within the range Hulse, et al. (1980) showed for cattle egret muscle (0.017-0.292 µg/g) and laughing gull muscle (<0.0010.109 µg/g) from Galveston Bay, Texas; and less than Nicholson (1981) showed for herring gull muscle in the North Atlantic ($\bar{x}$ = 0.25 µg/g) and

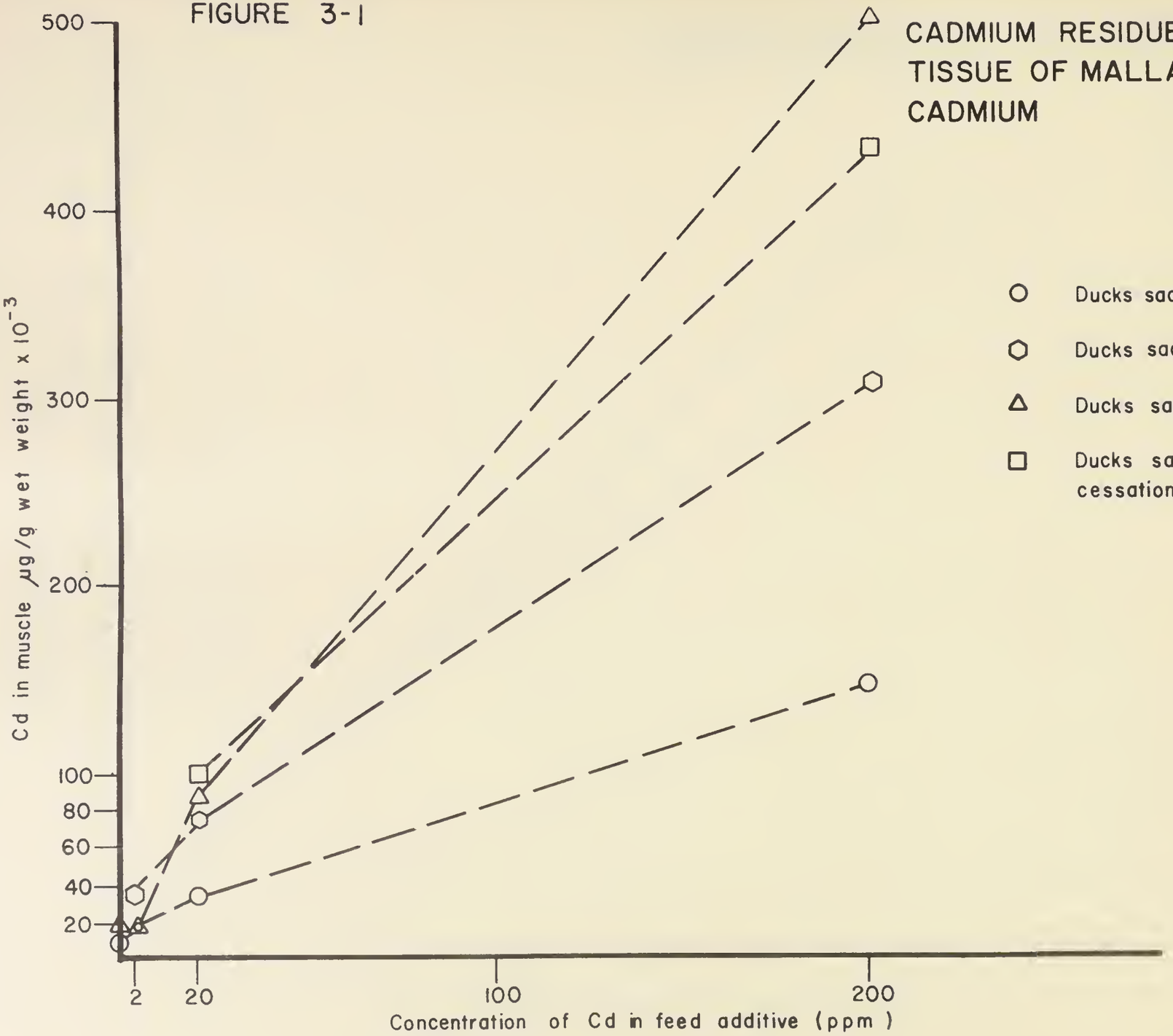
Stoneburner, et al. (1980) showed for sooty terns in the Dry Tortugus of Florida ($\bar{x}$ = 1.11 µg/g).

The five Warm Springs Ponds waterfowl liver tissues analyzed for cadmium had a concentration range of 1.35-4.53 µg/g. These values are greater than White, et al. (1979) showed for canvasback livers from the Cheasapeake Bay, Maryland (x=0.59 µg/g), than Blus, et al. (1977) showed for brown pelican livers from South Carolina (0.01-1.06 µg/g), than Turner, et al. (1978) showed for a group of shorebird livers from New Zealand (x=0.21-0.95 µg/g), and than Hulse, et al. (1980) showed for cattle egret livers from Galveston Bay, Texas (0.019-0.206 µg/g). The values are near the range Nicholson (1981) showed for herring gull livers from the North Atlantic (<0.25-3.9 µg/g), on the low end of the range Bull, et al. (1977) showed for North Atlantic pelagic seabird livers (1.4-57.0 µg/g), and in the same range that Stoneburner, et al. (1980) showed for sooty tern livers from the Dry Tortugas, Florida ($\bar{x}$=3.79 µg/g), and Furness and Hutton (1980) showed for great skuas livers from the North Atlantic (0.3-3.1 µg)/g. They are less than Anderlini, et al. (1972) showed for ashy petrel livers from a southern California breeding population ($\bar{x}$=53.2 µg/g). These data indicate Warm Springs Ponds waterfowl liver cadmium concentrations are within the ranges reported by other investigators for other locations.

White and Finley (1978) performed some cadmium feeding experiments with mallards; the data are shown in Figures 3-1 and 3-2. Extrapolating from these curves and the data for Warm Springs Ponds liver

FIGURE 3-1

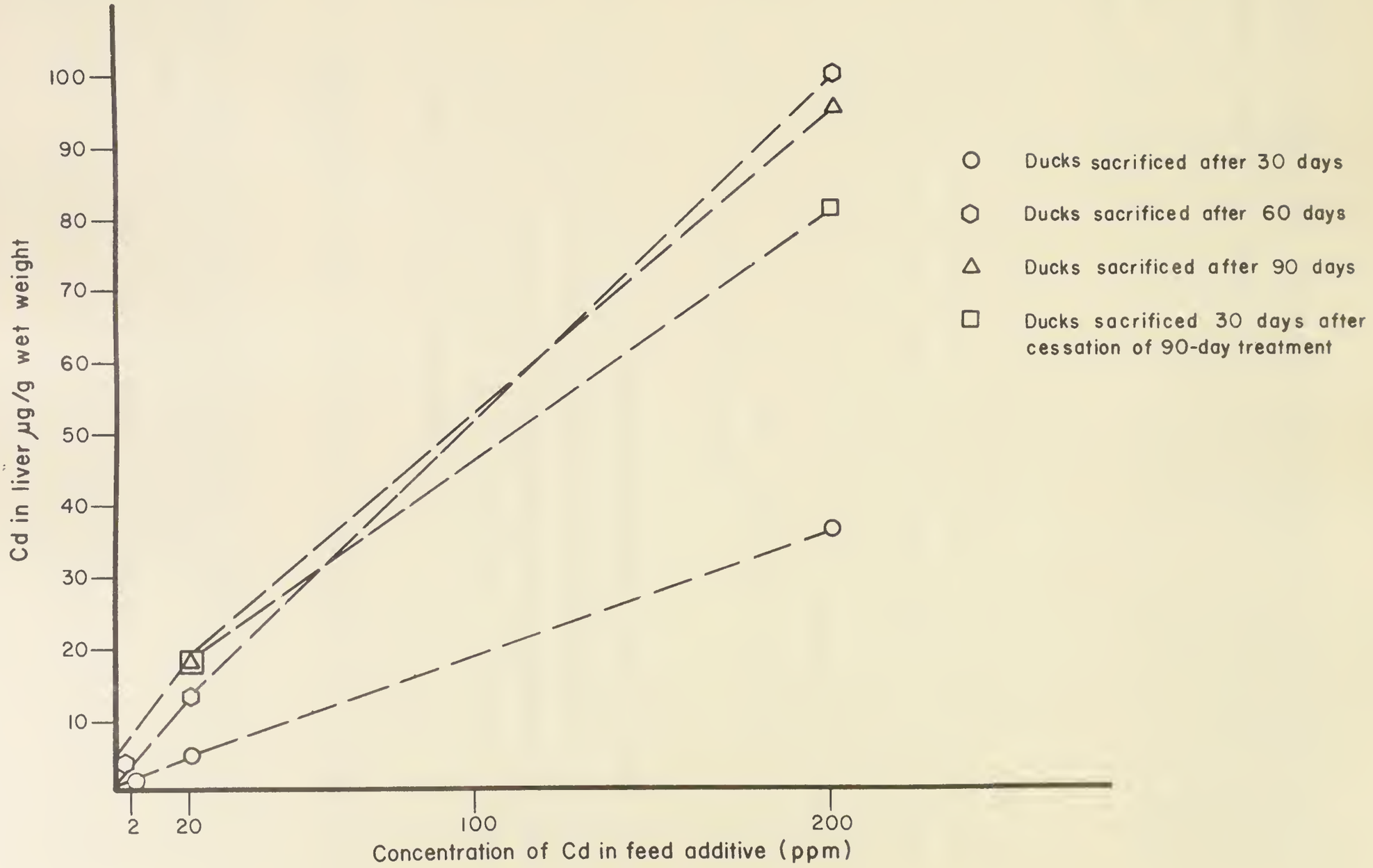
CADMIUM RESIDUES IN THE MUSCLE TISSUE OF MALLARD DUCKS FED CADMIUM



SOURCE: White and Finley 1978

FIGURE 3-2

CADMIUM RESIDUES IN THE LIVERS OF MALLARD DUCKS FED CADMIUM



SOURCE: White and Finley 1978

and muscle tissue, the Warm Springs Ponds waterfowl appear to be on a diet containing less than 5 ppm cadmium. Additionally, White and Finley's (1978) control muscle samples averaged 0.39 µg/g of cadmium, which is higher than the Warm Springs Ponds muscle averages of cadmium.

These conclusions depend on the accuracy of the method used to measure cadmium concentrations in the tissues. As previously discussed, the QA/QC data for cadmium (Attachment Table II-2) indicate that predigestion sample bank standards gave only 18 to 33% recovery on the first analysis run and 73 to 93% on re-analysis, suggesting that cadmium may not have been completely recovered in the first analysis of Q-samples 361 and 362.

As explained previously in the QA/QC discussion, Q361 and Q362 were solid dry samples which were digested in the same manner as the wet samples. These dry samples were effectively more concentrated than the wet samples and may not have been completely digested, causing the low recoveries for Q361 and Q362.

3.1.3.2 Statistical Tests of Cadmium Distribution in Waterfowl Tissues

Attachment Table IV-7 compares the average cadmium concentration in muscle tissue of Warm Springs Ponds waterfowl to the control samples. Attachment Table IV-8 compares the average muscle and liver tissue cadmium concentrations of the Warm Springs Ponds waterfowl.

Attachment Tables IV-9, IV-10, and IV-11 compare the average muscle tissue concentrations of Warm Springs Ponds waterfowl by age, sex, and subfamily, respectively.

Cadmium concentrations in Warm Springs Ponds waterfowl tissue were not significantly different from the control samples; therefore, this Silver Bow Creek contaminant does not appear to concentrate in the waterfowl muscle tissue. However, the average liver concentration of cadmium was significantly higher than the average muscle concentration. These data support the conclusion that cadmium is being concentrated in Warm Springs Ponds waterfowl liver tissues.

The only significant differences found in the age, sex, and subfamily comparisons were as follows:

- Using transformed data, the sex unknown samples appear to have significantly higher muscle cadmium concentrations than did the males (this is probably a function of juveniles not being sexed and showing high MDL's) and
- The puddle ducks (Anatinae) appear to have a significantly lower muscle cadmium concentration than did the diving ducks (Aythyinae).

The difference in cadmium concentrations between the diving ducks and puddle ducks may be due to the diving ducks being higher on the food chain than the puddle ducks.

Attachment Table IV-12 presents the coefficients of determination (r^2) for these relationships: cadmium concentrations in liver versus body weights; cadmium concentrations in muscle versus body weights; cadmium concentrations in muscle versus arsenic, copper, and zinc concentrations in muscle, and cadmium concentrations in liver versus arsenic, copper, and zinc concentrations in liver. No relationships were shown by these tests.

3.1.4 Copper

In small amounts copper is a necessary trace element in human diets. However, in large doses, it can cause toxic effects. For this reason, copper is regulated in public drinking water supplies (40 CFR 143). Copper is not regulated in food by the USDA (Spaulding 1985); however, the Canadian Food Directorate has a tolerance level for copper of 100 µg/g (Phillips 1982). Because copper was the primary metal extracted from the mining and milling activity in the upper reaches of the Silver Bow Creek/Clark Fork River basin, it was suspected as a potential contaminant in the system.

3.1.4.1 Copper Standards and Background Concentrations

Copper concentrations in the muscle and liver tissue of waterfowl from the Warm Springs Ponds are presented in Table 3-1. The comparison of these data to the USDA average and "high" values for copper in domestic waterfowl shows that copper concentrations in the muscle and liver tissues of Warm Springs Ponds waterfowl appear

similar to the USDA muscle and liver copper concentrations. The average muscle concentration of copper in Warm Springs Ponds waterfowl was 5.09 µg/g (<DL reported at the DL), compared to the USDA average of 3 µg/g. The average liver concentration of Warm Springs ponds waterfowl was 45.94 µg/g, compared to the USDA average of 60 µg/g (Spaulding 1985). Since the variation in the USDA samples was not given by Spaulding (1985), a statistical comparison was not possible.

Copper concentrations in Warm Springs Ponds waterfowl muscle tissue did not exceed the 100 µg/g tolerance level of the Canadian Food Directorate.

Attachment Table III-3 shows some examples of copper concentrations in waterfowl tissue from the literature. Ambient copper concentrations are given in this table, if known. Mean Silver Bow Creek waterfowl muscle concentrations of copper (4.84-5.09 µg/g) were in the same range as mean copper concentrations in the carcass of white-breasted cormorant from Lake McIlwaine, Rhodesia ($\bar{x}$ = 3.1 µg/g) (Greichus 1978).

Liver tissue concentrations of copper of the Warm Springs Ponds water fowl ranged from 19.4-93.9 µg/g. These values are in the same range as White, et al. (1979) found in the livers of Cheasapeake Bay canvasback ($\bar{x}$=59 µg/g), but higher than Blus, et al. (1977)

found in the livers of brown pelicans from South Carolina (4.3-9.0 μg/g) and Turner, et al. (1978) found in the livers of shorebirds in New Zealand ($\bar{x}$=3.39-9.77 μg/g). These data suggest copper concentrations in Warm Springs Ponds waterfowl tissue are not above natural background levels.

3.1.4.2 Statistical Tests of Copper Distribution in Waterfowl Tissue

Comparisons were made of copper concentrations between Warm Springs Ponds waterfowl muscle and liver tissue, between Warm Springs Ponds waterfowl muscle tissue and control sample muscle tissue, and among age, sex, and subfamily.

Attachment Table IV-13 compares the Warm Springs Ponds waterfowl average muscle tissue concentration of copper to that of the control samples; no significant difference was found. A very significant difference ($p<.01$) was found when comparing the Warm Springs Ponds waterfowl muscle tissue copper concentration to the average copper concentration of the liver tissues analyzed (Attachment Table IV-14). No significant differences were found between the average muscle concentration of copper of age classes, sexes, or subfamily groups (Attachment Tables IV-15, IV-16, and IV-17, respectively).

Significantly higher liver concentrations of copper in Warm Springs Ponds waterfowl may be attributable to the liver function of removing contaminants from the blood.

Table IV-18 presents the coefficients of determination (r^2) for the following: copper concentrations in liver versus body weights; copper concentrations in muscle versus body weights; copper concentrations in muscle and liver versus arsenic, cadmium, and zinc concentrations in muscle and liver, respectively. Only arsenic versus copper concentrations in liver showed a relationship, with an r^2 of 0.87 - 0.97.

3.1.5 Zinc

Zinc, like copper, is a necessary trace element in human diets, but it too can cause toxic effects in large doses. For this reason, zinc is regulated in public drinking water supplies (40 CFR 143). Zinc is not regulated by the USDA in food (Spaulding 1985), but the Canadian Food Directorate has a tolerance level for zinc of 100 µg/g (Dent 1977). Because zinc occured in the ores mined and milled in the Silver Bow Creek drainage, it was suspected as a contaminant in the hydrologic system.

3.1.5.1 Zinc Standards and Background Concentrations

Warm Springs Ponds waterfowl muscle concentrations of zinc ranged from 7.68-22.4 µg/g. No samples exceeded the Canadian standard of 100 µg/g (Dent 1977).

The USDA has no data on zinc concentrations in the tissues of domestic waterfowl as presented previously for arsenic, cadmium, and copper (Table 3-2).

Attachment Table III-4 gives some examples of zinc concentrations in waterfowl tissue from the literature. Ambient zinc concentrations are presented in this table, if known. Warm Springs Ponds waterfowl muscle tissue zinc concentrations ($\bar{x}$=13.3 µg/g) are lower than Nicholson (1981) found in North Atlantic herring gull muscle ($\bar{x}$=58.7) and Greichus et al. (1978) found in cormorant carcasses in Rhodesia ($\bar{x}$ = 77 µg/g). Warm Springs Ponds waterfowl liver tissue concentrations of zinc (33.7-54.4 µg/g) are in the same range as canvasback livers from the Cheasapeake Bay ($\bar{x}$=41 µg/g; White 1979), herring gull livers from the North Atlantic ($\bar{x}$=66.6 µg/g; Nicholson 1981), brown pelican livers from South Carolina (26-55 µg/g; Blus et al. 1977), and several species of shorebirds from New Zealand (27.5-44.3 µg/g; Turner et al. 1978). No literature sources showed lower zinc concentrations than the Warm Springs Ponds waterfowl. However, these data suggest zinc does not occur at concentrations greater than natural background in Warm Springs Ponds waterfowl.

3.1.5.2 Statistical Tests of Zinc Distribution in Waterfowl Tissue

The control sample average muscle zinc concentration was not significantly different from that in Warm Springs Ponds Waterfowl (Attachment Table IV-19). However, average zinc concentrations in Warm Springs Ponds waterfowl liver tissue was very significantly

different ($p<0.01$) from the average zinc concentration in the muscle tissue (Attachment IV-20). Significant differences also were shown for the age class comparison, sex comparison, and subfamily comparison (Attachment Tables IV-21, IV-22, and IV-23, respectively).

The coefficients of determination (r^2) for zinc concentrations are presented in Attachment IV-24. Coefficients were calculated for zinc concentrations in liver versus body weights; zinc concentrations in muscle versus body weight; zinc concentrations in muscle versus arsenic, cadmium, and copper concentrations in muscle; and zinc concentrations in liver versus arsenic, cadmium, and copper concentrations in liver. No relationships were revealed by these tests.

3.2 ORGANIC DATA

Five waterfowl muscle samples and five waterfowl liver samples were analyzed for pentachlorophenol (PCP) and polychlorinated biphenyls (PCB). Sample data are presented in Table 3-3 and summarized in Table 3-4. One of the muscle samples was a control sample collected near Dillon, Montana, so only four muscle samples are from the Warm Springs Ponds area.

TABLE 3-3

PCP AND PCB CONCENTRATIONS IN WARM SPRINGS PONDS AND ONE CONTROL WATERFOWL

Lab No.[a]	Age	Sex	Species	Muscle[b] PCP	Muscle[b] Lipid PCP[c]	Muscle[b] PCB[d]	Muscle[b] Lipid PCB[d,e]	Liver[b] PCP	Liver[b] Lipid PCP[c]	Liver[b] PCB[d]	Liver[b] Lipid PCB[d,e]
T001-M, L	A	M	Goldeneye	0.297	41.2	0.180	25.0	0.130	14.5	0.168	18.7
T007-M	A	M	Mallard	0.365	38.1	0.050	5.21	--	--	--	--
T012-M	A	M	Goldeneye	0.413	65.1	0.070	10.9	--	--	--	--
T015-L	J	-	Canada Goose	--	--	--	--	0.016	1.39	<0.01	<0.87
T016-L	J	-	Canada Goose	--	--	--	--	<0.005	<0.759	<0.01	<1.52
T018-M, L	J	-	Canada Goose	0.017	8.67	<0.01	<5	0.038	3.38	<0.01	<0.89
T023-L	J	-	Redhead	--	--	--	--	<0.005	<0.388	0.080	5.41
T042-M[f]	A	-	Mallard	<0.005	<0.672	<0.01	<1.35	--	--	--	--

(a) M = muscle, L = liver.
(b) ppm wet weight.
(c) Lipid basis calculated as $\frac{\text{mg PCP}}{\text{kg lipid}}$
(d) Arclor 1260.
(e) Lipid basis calculated as $\frac{\text{mg PCB}}{\text{kg lipid}}$
(f) Control sample from near Dillon, Montana.

TABLE 3-4
MEANS, STANDARD, ERRORS, RANGES AND FOOD STANDARD COMPARISONS
FOR PCP AND PCB IN WARM SPRINGS PONDS WATERFOWL

Compound	No.	MEAN(a,b)	SE(a,b)	RANGE(b)	FOOD STANDARD(b)
PCP in Muscle	4	0.273	0.088	0.017-0.43	10 mg/kg bw/day(c)
Lipid PCP in Muscle	4	38.3	11.6	8.67-65.1	
PCB in Muscle	4	0.078	0.036	<0.01-0.18	(d)
Lipid PCB in Muscle	4	11.5	4.69	<5.0-25.0	3.0(d)
PCP in Liver	5	0.039	0.024	<0.005-0.13	10 mg/kg bw/day(c)
Lipid PCP in Liver	5	4.08	2.65	<0.388-14.5	None Found
PCB in Liver	5	0.056	0.031	<0.01-0.168	(d)
Lipid PCB in Liver	5	5.47	3.41	<0.87-18.7	3.0(d)

(a) Mean and standard error (SE) calculated with those values <MDL reported at the MDL.
(b) ppm wet weight; bw = body weight.
(c) Based on USEPA (1985) One-Day Health Advisory for water.
(d) Standard for PCB in food is based on rendered fat (Spaulding 1986).

3.2.1 Quality Assurance and Quality Control Considerations

Attachment Table II-5 presents the QA/QC data generated for the analysis of PCB and PCP in waterfowl tissue. SBC RI Waterfowl samples were analyzed with SBC RI fish tissue samples (Appendix E, Part 3) so they share common QA/QC data.

Instrument level QA/QC data is available from the contract lab. Sample bank blanks (prepared by MultiTech) showed no contamination problems for either PCB or PCP. The sample bank duplicates showed good agreement, with the PCP DSA% = 114% and the lipid-based PCB DSA% = 98%. The sample bank standards showed the lowest recoveries, with PCB KSA% = 69% and the PCP KSA% = 35%.

3.2.2 PCP

Pentachlorophenol has been listed by the USEPA as a hazardous waste under the Resource Conservation and Recovery Act of 1976 (RCRA). PCP was selected for analysis in waterfowl tissue for the SBC RI as Silver Bow Creek is known to receive PCP-bearing oil from an abandoned post and pole treatment plant. This analysis was done as part of the SBC RI, at the request of the Montana Department of Fish, Wildlife, and Parks, but the post and pole treatment plant was removed from the SBC RI site and given separate status.

3.2.2.1 PCP Standards and Background Concentrations

Table 3-5 presents the water quality data for PCP collected as part of the SBC RI and compares the data to a proposed water quality criteria for PCP. The water quality data for PCP was collected upstream and downstream of the known point source of PCP. The lowest downstream site sampled for PCP was SS-07, which is 22.3 stream miles above the Warm Springs Ponds.

As seen in Table 3-5, the proposed water quality criterion for PCP was exceeded at the stations sampled on several occasions. PCP water quality data was not collected at the Warm Springs Ponds, as the concentrations would likely be diluted to the point of being unmeasurable. An approach that documented bioaccumulation, prior to addressing pathways, was selected for all SBC RI biological tissue studies.

Waterfowl from the Warm Springs Ponds had measurable amounts of PCP on a wet weight basis and on a lipid basis (Table 3-4). The EPA has a draft Health Advisory (HA) for PCP calculated for a 10-kg (22-lb) child as follows (USEPA 1985):

$$\text{One day HA} = \frac{(\text{NOAEL})\ (\text{BW})}{(\text{UF})(\text{L/day})} = \mu g/L \qquad (1)$$

where: NOAEL = No observed adverse affect level (the exposure dose in mg/kg bw)

BW = Body weight in kg

UF = Uncertainty factor

L/day = Assumed daily water consumption

TABLE 3-5

PCP CONCENTRATIONS IN SURFACE WATER FOR SBC RI, 1984-1985

Station	Location	Dates	Concentrations (ppm)	Proposed WQ Criteria[b] (ppm)
SS-06	Just below Montana Post and Pole, above Colorado Tailings.	12-3-84	0.054[a]	.048
SS-07	Several hundred yards downstream of Montana Post and Pole, below Colorado Tailings.	12-4-84	0.055[a]	.048
SS-06	See above	2-25-85	0.200[a]	.048
SS-06 Dup		2-25-85	0.240[a]	.048
SS-07	See above	2-25-85	0.014[a]	.048
SS-06	See above	4-22-85	0.025[a]	.048
SS-06 Dup		4-22-85	0.027[a]	.048
SS-07	See above	4-22-85	0.048[a]	.048
SS-05	Above Montana Post and Pole, below Montana Street Bridge.	7-22-85	<0.00044[a]	.048
SS-06	See above	7-22-85	0.029	.048
SS-07	See above	7-22-85	0.019	.048

(a) Analyzed post holding time.
(b) Hedtke and Arthur 1985.

$$\text{One day PCP HA} = \frac{(10\ \text{mg/kg/day})\ (10\text{kg})}{(100)\ (1\ \text{L/day})} \qquad (2)$$

$$= 1.0\ \text{mg/L}$$

Using the data provided in these equations one can calculate (using the UF of 100) that the daily HA intake equals 1.0 mg/day for a 10 kg child. Using the worst-case PCP concentration of 0.413 µg/g wet weight in Warm Springs Ponds waterfowl muscle tissue yields an intake of 2421 g, or 5.33 lbs of muscle tissue, per day to reach the 1 mg limit of PCP per day. The Ten-Day and Lifetime Health Advisories are 0.3 of the One-Day Health Advisory, indicating a 10 kg child would have to consume 1.6 lbs/day of the worst-case tissue to exceed the No Observed Adverse Effect Level (NOAEL).

3.2.2.2 Statistical Tests of PCP Distribution in Waterfowl Tissues

PCP in muscle on a lipid basis showed a relationship with PCP on a wet weight basis (coefficient of determination=0.85). PCP in muscle showed no relationship with PCB concentrations in muscle on a wet weight-wet weight basis (coefficient of determination = 0.17), a wet weight-lipid basis (coefficient of determination = 0.07) or a lipid-lipid basis (coefficient of determination = 0.11).

Mean PCP concentrations on a wet weight basis and lipid basis were higher than mean PCB concentrations on wet weight basis and lipid basis, but were not significantly higher ($p>.05$). However, mean PCP concentrations in waterfowl muscle were significantly ($p<.05$)

higher than mean PCP concentrations in waterfowl liver on both a wet weight and lipid basis.

These data indicate that PCP probably concentrates more in waterfowl muscle than in the liver, and that factors that contribute to PCP and PCB concentrations in Warm Springs Ponds waterfowl are probably unrelated.

3.2.3 PCB

Polychlorinated biphenyls (PCB) are synthetic, chlorinated hydrocarbons. Major PCBs manufactured are Aroclor® 1221, 2132, 1242, 1248, 1254, 1260, 1262, and 1268; the last two digits in the number signify the percentage of chlorine in the compound. PCBs are poorly soluble in water, are soluble in fats and concentrate in them, and increase in food chains (Heath et. al. 1972, in Schladweiler and Weigand 1983). PCBs have been listed under RCRA as a hazardous waste. They were identified for analysis in SBC RI ducks by the request of MDFWP, because PCBs are potential contaminants from the Butte urban area.

3.2.3.1 PCB Standards and Background Concentrations

Tables 3-3 and 3-4 indicate that three of the four waterfowl analyzed for PCB in their muscle exceeded the USDA standard for PCB in food. One of the waterfowl from the Warm Springs Ponds and the offsite

control sample from near Dillon, Montana were less than the 3.0 ppm standard.

Table 3-6 presents PCB concentration data for waterfowl in Montana collected by Schladweiler and Weigand (1983). Comparing their data to SBC RI waterfowl data is difficult because of the tissue types and units of reporting. For those samples called "meat" in Table 3-6 reported on wet weight basis, the range of PCB concentrations was <0.01-0.94 ppm, with only two samples showing detectable levels (0.94 and 0.76 ppm). This compares with the range of Warm Springs Ponds waterfowl of 0.01-0.18 ppm wet weight.

For a fat tissue sample as analyzed by Schladweiler and Weigand the wet weight concentration should be near the lipid-based concentration, as the fat tissue is mostly lipids. Assuming that the wet-weight concentrations for fat tissues in Table 3-6 are representative of a lipid-based concentration in the tissue, the Warm Springs Ponds lipid-based data for muscle tissue is higher than the concentrations reported by Schladweiler and Weigand ($\bar{x}$=11.5 vs $\bar{x}$=2.32). The significance of this difference is difficult to assess, given the RI study small sample size and the different tissue types.

Attachment Table III-5 presents some data for PCB concentrations in waterfowl tissue from the literature. White et. al. (1979) reported concentrations of PCB's in canvasback carcasses from the Cheasapeake Bay, Maryland on a wet weight basis. His means of 1.5 and 2.7 ppm are considerably higher than the Warm Springs Ponds waterfowl muscle

TABLE 3-6
SUMMARY OF PCB RESIDUES DETECTED IN TISSUES OF WATERFOWL IN MONTANA. 1981-1982, BY MDFWP[a]

Species	Period Sampled	No. Birds	No. Samples Tested	Detection Level	No. Below Detection Level	Detectable Residues (ppm)[b] No.	Levels
Canada Goose	Aug-Sept 1981	34	33 fat	0.10	32	1	0.13
	Nov-Dec 1981		1 meat	0.10	1	0	--
	Mar-May 1982		1 brain	0.05	1	0	--
	July-Aug 1982		1 egg	0.10	1	0	--
	Oct 1982		1 food	0.10	1	0	--
Whistling Swan	Oct 1982	4	4 fat	0.10	4	0	--
Baldpate/Wigeon	Sept-Nov 1981	23	21 fat	0.10	18	3	0.15, 0.28, 0.29
	Apr-Aug 1982		1 meat	0.01	1	0	--
			3 brain	0.10	3	0	--
			2 food	0.01	1	1	0.053
Blue-winged Teal	Sept 1981	18	17 fat	0.10	10	7	0.15, 0.24, 0.50, 0.73
	May 1982						0.77, 0.84, 50.10
	July-Sept 1982		1 meat	0.10	0	1	0.94
			2 food	0.10	2	0	--
Gadwall	Sept-Nov 1981	22	21 fat	0.10	18	3	0.28, 0.73, 2.41
	June-Aug 1982		1 meat	0.05	1	0	--
	Oct 1982						
Green-winged Teal	Oct 1981	5	5 fat	0.10	3	2	0.23, 0.93
	Apr-May 1982		1 meat	0.10	1	0	--
	Oct 1982		1 brain	0.05	0	1	0.053
			1 food	0.05	0	1	0.075
Mallard	Sept-Nov 1981	58	56 fat	0.10	43	13	0.12, 0.15, 0.16, 0.22,
	Feb 1982						0.30, 0.56, 0.56, 0.67,
	Apr-May 1982						0.80, 0.84, 3.37, 4.44
	July-Oct 1982						5.82
			4 meat	0.10	4	0	--
			1 cooked meat	0.10	1	0	--
			1 brain	0.05	0	1	0.53
			1 food	0.05	1	0	--
			2 egg	0.10	2	0	--

TABLE 3-6

SUMMARY OF PCB RESIDUES DETECTED IN TISSUES OF WATERFOWL IN MONTANA. 1981-1982, BY MDFWP[a] (Cont.)

Species	Period Sampled	No. Birds	No. Samples Tested	Detection Level	No. Below Detection Level	Detectable Residues (ppm)[b] No.	Levels
Pintail	Apr-May 1982	13	12 fat	0.10	9	3	0.21, 0.39, 0.52
	July 1982		3 meat	0.10	3	0	--
	Sept-Oct 1982		3 brain	0.05	3	0	--
			2 food	0.05	2	0	--
Ring-necked Duck	Oct 1981 Apr, Sept 1982	4	4 fat	0.10	3	1	0.15
Ruddy Duck	Oct 1981 July 1982	3	3 fat	0.10	3	0	--
Lesser Scaup	Oct 1981 Apr, Aug Oct 1982	9	9 fat	0.10	5	4	0.18, 0.18, 0.19, 2.91
Shoveler	Oct 1981	5	5 fat	0.10	1	4	0.20, 0.26, 3.36, 14.40
	Apr-May 1982		1 meat	0.10	0	1	0.76

(a) Source: Schladweiler and Weigand 1983.
(b) Primarily wet weight basis, but a few may be on a lipid basis.

PCB mean (on a wet weight basis) of 0.273 ppm. Furness and Hutton (1980) measured the wet weight concentrations of PCBs in great skuas, a pelagic seabird, and reported geometric means of 15.9 and 16.0 ppm for two separate breeding populations.

Blus, et. al. (1977), Greichus, et. al. (1978), and Peterson and Ellarson (1978) showed PCB Concentrations in muscle or carcass ten times greater than Warm Springs Ponds waterfowl in brown pelicans, white breasted cormorants, and old squaw, respectively. All of the examples, except for White (1979) are species higher on the food chain than the majority of Warm Springs Ponds waterfowl, which may explain their higher tissue concentrations.

Turner, et. al. (1978) measured PCB concentrations in the muscle tissue of several species of shorebirds (gulls and stilts) which may more closely resemble the trophic status of the mix of species in this study. His mean concentrations ranged from .03-2.87 ppm wet weight as compared to the range of Warm Springs Ponds waterfowl muscle concentration range of 0.017-0.43 ppm wet weight.

Custer and Heinz (1980) fed mallards PCBs, then tested their carcasses for PCB concentrations. Their controls showed a mean background concentration of 0.01 ppm wet weight, and their experimental samples fed a diet of 25 ppm PCB showed a mean concentration of 4.0 ppm PCB for males and 1.9 ppm PCB for females (wet weight).

Warm Springs Ponds waterfowl show PCB concentrations higher than Custer and Hienz's (1980) control samples, indicating that the Warm Springs Ponds waterfowl are probably carrying a higher than normal (or background) load of PCBs. Based on the data of Custer and Hienz, this load is probably due to a diet of less than 25 ppm PCB's.

Because waterfowl are migratory, the source of the PCB load carried by Warm Springs Pond waterfowl cannot be identified without more data. However, the SBC RI Fish Tissure Investigation Report documented elevated levels of PCBs in fish spending most of their life span in the Warm Springs Ponds, indicating a possible local source of PCB contamination.

3.2.3.2 Statistical Tests of PCB Distribution in Waterfowl Tissues

PCB in muscle on a lipid basis showed a relationship with PCB on a wet weight basis (coefficient of determination >0.95). As stated previously in the section on PCP, PCB and PCP exhibited no relationships in concentration in Warm Springs Ponds waterfowl tissues. PCB means and PCP means showed no significant differences in contamination in muscle or liver tissues ($p>.05$) on either a wet weight or lipid basis; PCB showed no significant differences in mean concentration between muscle and liver tissue.

The data indicate that PCBs were not differentially distributed between the muscle and liver tissue and that factors that contribute to PCP and PCB concentrations in Warm Springs Ponds Waterfowl are probably unrelated.

DRAFT

4.0 CONCLUSIONS

4.1 METALS

Cadmium is the only metal which appears in elevated concentrations in Warm Springs Ponds Waterfowl. The high cadmium concentrations are specifically in liver tissue, and not in the muscle tissue.

Arsenic, copper, and zinc concentrations are not elevated above background in either the muscle or liver tissue from Warm Springs Ponds waterfowl, although the copper and zinc differentially concentrate in the liver tissue as compared to the muscle tissue.

4.1.1 Arsenic

Warm Springs Ponds waterfowl do not appear to be concentrating arsenic in their tissues, and none of the samples for which concentrations were calculated had concentrations above the USDA standard of 0.70 µg/g.

Mean arsenic concentrations did not appear to be different between Warm Springs Ponds waterfowl muscle tissue and control samples muscle tissue. Arsenic did not appear to be differentially distributed between muscle and liver tissue in the samples analyzed. No significant differences were noted between mean muscle arsenic concentrations of males vs. females or among the various types: puddle ducks (Antinae), diving ducks (Aythyinae), and geese (Anserinae).

High MDLs for juvenile samples were caused by low weight sample sizes, which biased data for age group comparisons. Arsenic concentrations in muscle did not appear to be correlated to cadmium, copper, or zinc concentrations in muscle. Arsenic concentrations in the liver appeared to correlate only with copper concentrations in the liver.

4.1.2 Cadmium

Data collected on cadmium concentrations in Warm Springs Pond waterfowl tissues suggest that these waterfowl are concentrating cadmium in their liver tissue: the mean liver cadmium concentrations appeared significantly higher than the mean muscle cadmium concentration for Warm Springs Ponds waterfowl.

The mean muscle cadmium concentrations of Warm Springs Ponds waterfowl did not appear significantly different from the control samples, although puddle duck (Antinae) appeared to have a significantly lower muscle cadmium concentration than did the diving ducks (Aythyinae). No standards are established for cadmium in food; however, based on the FAO/WHO provisional tolerable weekly intake of 500 µg/week, a person would have to eat 13.7 oz. of duck muscle per week of the worst-case muscle sample (1.27 µg/g) to reach the standard, or using the mean muscle concentration of 0.16 µg/g, a person would have to eat 116 oz. (7.3 lbs) of duck muscle to reach the standard.

Cadmium did not appear correlated with any other metal concentrations in either the muscle or the liver.

4.1.3 Copper

Warm Springs Ponds waterfowl do not appear to be concentrating copper in their muscle tissue, and none of the samples analyzed were above the Canadian Food Directorate tolerance level of 100 µg/g. Mean copper concentrations of Warm Springs Ponds waterfowl muscle tissue did not appear to be significantly different from the mean copper concentration of control sample muscle tissue. No significant differences in copper concentrations were detected for age classes, sexes, or subfamily groups. Copper did appear to be differentially distributed between muscle and liver tissue for those samples analyzed. Copper did not appear to be correlated with the other metals, except with arsenic in liver tissue.

4.1.4 Zinc

Zinc concentrations measured in Warm Springs Ponds waterfowl muscle tissue did not exceed the Canadian Food Directorate tolerance level of 100 µg/g. Muscle and liver tissue concentrations of zinc in Warm Springs Ponds waterfowl did not appear to be elevated above normal background.

Mean zinc concentrations in the muscle tissue of Warm Springs Ponds waterfowl did not appear to be significantly different from that

in the muscle tissue of the control samples. However, zinc did appear to be differentially distributed, showing higher values in liver tissue than in muscle tissue. Zinc also appeared to be distributed differently in the muscle tissue by age, sex, and subfamily groups. Zinc showed no correlation with the other metals in either muscle or liver tissue.

4.2 ORGANICS

4.2.1 Pentachlorophenol (PCP)

Investigation data indicate that Warm Springs Ponds waterfowl are carrying a body burden of PCP. A 10 kg child would have to consume 5.33 lbs/day or 1.6 lbs/day of the highest PCP concentration muscle to consume the USEPA One-Day Health Advisory amount of 1.0 mg/day (USEPA 1985), or consume 1.6 lbs/day to reach the USEPA Ten-Day and Lifetime Health Advisory amount of 0.3 mg/day.

PCP in muscle tissue on a lipid basis was related to PCP in muscle tissue on a wet weight basis. PCP and PCB concentrations did not appear to be related. PCP concentrations appeared to be significantly higher in muscle tissue than in liver tissue.

4.2.2 Polychlorinated Biphenyls (PCB)

Three of four Warm Springs Ponds waterfowl muscle tissues analyzed for PCB showed a lipid based residue concentration greater than

the USDA standard for food of 3.0 ppm. The single offsite sample had a PCB concentration of less than the standard.

Literature data suggest that PCB contamination is a widespread problem, with PCB tissue concentrations found above and below those reported for Warm Springs Ponds waterfowl.

PCB residues in Warm Springs Ponds Fish (reported in the SBC RI Fish Tissue Investigation Report, Appendix E, Part 3) indicate a possible local source of PCB contamiation.

PCB and PCP did not appear to be related in Warm Springs Ponds waterfowl tissue. PCB concentrations in muscle on a lipid basis were related to PCB concentrations in muscle on a wet weight basis. PCB did not appear to be differentially distributed between muscle tissue and liver tissue.

Human health risks and migration pathways will be evaluated in the public health assessment during the Feasibility Studies using the data presented in this report.

REFERENCES

Anderlini, V.C., P.G. Conners, R.W. Risebrough, and J.H. Martin. 1972. In Proceedings on the Conservation and Problems of Antarctica, B.C.Parker(ed.) Virginia Polytechnic Institute and State University, Blacksburg, Virginia. pp. 49-62.

Blus, L.J., B.K. Neely, Jr., T.G. Lamont, and B. Mulhern. 1977. Residues of Organochlorines and Heavy Metals in Tissues and Eggs of Brown Pelicans, 1969-73. Pesticides Monitoring Journal. 11(1): 40-53.

Bull, K.R., R.K Murton, D. Osborn, P. Ward, and L. Cheng. 1977. High levels of Cadmium in Atlantic Seabirds and Sea-Skaters. Nature. 269: 507-509.

Champa, L. (February 24) 1965. Internal Memo to L.W. Brink. Montana State Department of Health, Helena, Montana.

40 CFR 141 and 143. 1981. Code of Federal Regulations, Office of the Federal Register, Washington, D.C.

Cornish, J.C. (MultiTech). 1984. Anaconda Smelter Soils/Cropland Sampling and Analysis Study Plan. For Ecology and Environment, Denver, Colorado and Region 8, USEPA, Denver, Colorado.

Custer, T.W. and G.H. Heinz. 1980. Reproductive Success and Nest Attentiveness of Mallard Ducks Fed Aroclor 1254. Environmental Pollution. 21:313-318.

Dent, R.L. 1977. Memorandum to George McArthur, Director of Environmental Affairs, MMD. Anaconda Minerals Company, Environmental Engineering Department. In Neher and Weisel 1977.

FAO/WHO Expert Committee on Food Additives. 1972. WHO Technical Report Series, 16th Report, No. 505.

Furness, R.W., and M. Hutton. 1980. Pollutants and Impaired Breeding of breat Skuas (Catharacta skua) in Britan. Ibis. 122: 88-94.

Greene, B. 1984. Personal Communication. Warm Springs Ponds Wildlife Management Area Manager, Montana Department of Fish, Wildlife, and Parks, Warm Springs, Montana.

Greichus, Y.A., A. Greichus, H.A. Draayer, and B. Marshall. 1978. Insecticides, Polychlorinated Biphenyls and Metals in African Lake Ecosystems. II. Lake McIlwaine, Rhodesia. Bulletin of Environmental Contamination and Toxicology. 007-4861/78/0019-0444. pp. 444-453.

Heath, R.G., J.W. Spann, J.F. Kreitzer, and C. Vance. 1972. Effects of Polychlorinated Biphenyls on Birds. Proceedings of the International Ornithologist Congress. 15:475-485.

Hedtke, S.F. and J.W. Arthur. 1985. Evaluation of Site-Specific Criterion Using Outdoor Experimental Streams. Monticello Ecological Research Station, USEPA Environmental Station, USEPA Environmental Research Lab, Duluth, Michigan EPA/600/D-85/041.

Hooper, B. (February 17) 1971. Internal Memo to L.W. Brinck. Montana State Department of Health, Helena, Montana.

Hulse, M., J.S. Mahoney, G.D. Schroder, C.S. Hacker, and S.M. Pier. 1980. Environmnetally Acquired Lead, Cadmium, and Manganese in the Cattle Egret (Bubulcus ibis) and Laughing Gull (Larus atricilla). Archives of Environmental Contamination and Toxicology. 9: 65-78.

Hydrometrics. 1983. Summit and Deer Lodge Valleys Long-Term Environmental Rehabilitation Study, Butte-Anaconda, Montana, Volume VI: Silver Bow Creek. For the Anaconda Minerals Company, Butte, Montana.

Leach, R.M., K.W.L. Wang, and D.E. Baker. 1979. Cadmium and the Food Chain: The Effect of Dietary Cadmium On Tissue Composition In Chicks and Laying Hens. Journal of Nutrition. 109(3): 437-443.

Maedgan, J.L., C.S. Hacker, G.D. Schroder, and F.W. Weir. 1982. Bioaccumulation of Lead and Cadmium in the Royal Tern and Sandwich Tern. Archives of Environmental Contamination and Toxicology. 11: 99-102.

MultiTech and Stiller and Associates. 1984a. Silver Bow Creek Remedial Investigation Work Plan. For the Montana Department of Health and Environmental Sciences, Helena, Montana.

MultiTech and Stiller and Associates. 1984b. Silver Bow Creek Remedial Investigation Quality Assurance/ Quality Control Program. For the Montana Department of Health and Environmental Sciences, Helena, Montana.

NWA. 1984. NWA STATPAK. Northwest Analytical, Inc. 1532 S.W. Morrison Street, Portland, Oregon.

Neher, M.A. and G.F. Weisel. 1977. Heavy Metal Accumulation and Its Effects on the Biota of an Industrial Settling Pond. Montana University Joint Water Resources Research Center, Bozeman, Montana. Report No. 90.

Newman, J.R. Effects of Air Emissions on Wildlife Resources. USFWS National Power Plant Team, Office of Biological Services. FWS/OBS-80/40.1

Nicholson, J.K. 1981. The Comparative Distribution of Zinc, Cadmium, and Mercury in Selected Tissues of the Herring Gull. (Larus argentatus). Comparative Biochemistry and Physiology. 68(c): 91-94. (Great Britain).

Peterson, S.R. and R.S. Ellarson. 1978. p, p*-DOE, Polychlorinated biphenyls, and Endrin in Oldsquaws in North America. Pesticides Monitoring Journal. 11(4):170-181.

Phillips, G.R. 1982. Metals Residues in Brown Trout (Salmo trutta) from The Clark Fork and Little Blackfoot Rivers, 1978. Montana Department of Fish, Wildlife, and Parks. Helena, Montana.

Rubich, Mike. 1984. Personal Communication. Environmental Engineer, Solid and Hazardous Waste Bureau, Helena, Montana. December 20, 1984.

Rubich, Mike. 1985. Personal Communication. Environmental Engineer, Solid and Hazardous Waste Bureau, Helena, Montana. January 24, 1985.

Schladweiler, P. and J.P. Weigand. 1983. Relationships of Endrin and Other Chlorinated Hydrocarbon Compounds to Wildlife in Montana, 1981-1982. Montana Department of Fish, Wildlife, and Parks, Helena, Montana.

Shambaugh, N. 1983. Heavy Metal Accumulation in the Biota of the Warm Springs Settling Ponds, Deer Lodge County, Montana. Paper for Botany 556, University of Montana, Missoula, Montana. December 10, 1983.

Stoneburner, D.L., P.C. Patty, and W.B. Robertson, Jr. 1980. Evidence of Heavy Metal Accumulation in Sooty Terns. The Science of the Total Environment. 14: 147-152.

Skaar, P.D. 1985. Montana Bird Distribution. Monograph No. 3. Montana Acadamy of Sciences, Supplement to the Proceedings. Volume 44. Montana Department of Fish, Wildlife and Parks Bozeman, Montana.

Spaulding, Dr. John. 1985. Personal Communication. Director, Residue Evaluation and Surveillance Division, Food Safety and Quality Service, US Department of Agriculture, Washington, D.C.

Spaulding, Dr. John. 1986. Personal Communication. Director, Residue Evaluation and Surveillance Division, Food Safety and Quality Service, US Department of Agriculture, Washington, D.C.

Stoecker, P. 1984. Personal Communication. Past President, Pintlar Chapter of the Audubon Society, Georgetown Lake, Montana.

Torrey, S. 1978. Trace Contaminants From Coal. Noyes Data Corporation, Park Ridge, New Jersey.

Trout, R.G. (MultiTech). 1983. Waterfowl Observations at The Warm Springs Ponds. Unpublished Notes.

Turner, J.C., S.R.B. Solly, J.C.M. Mol-Krijnen, and V. Shanks. 1978. Organochlorine, Fluorine, and Heavy-metal Levels in Some Birds from New Zealand Estuaries. New Zealand Journal of Science. 21: 99-102.

USDA. No Date. MPI Directive 917.1, Rev. 2, Exhibit F. Received From Glenn Phillips, Montana Department of Fish, Wildlife and Parks. Montana Department of Fish, Wildlife and Parks, Helena, Montana.

USEPA. 1981. Biological Monitoring of Trace Elements. Environmental Monitoring Systems Laboratory, Las Vegas, Nevada. EPA-600/53-80-090.

USEPA. 1982. Methods for Organic Chemical Analysis of Municipal and Industrial Waste Water. USEPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. EPA-600/4-82-057.

USEPA. 1983. Methods for the Chemical Analysis of Water and Wastes. USEPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. EPA-600/4-79-020.

USEPA. 1984. Characterization of Hazardous Waste Sites--A Methods Manual. Volume III: Available Laboratory Analytical Methods. USEPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada. EPA-600/4-84-038.

USEPA. 1985. Draft Health Advisory for Pentachlorophenol. USEPA Office of Drinking Water. September 30, 1985.

White, D.H. and M.T. Finley. 1978. Uptake and Retention of Dietary Cadmium in Mallard Ducks. Environmental Research. 17: 53-59.

White, D.H., R.C. Stendell, and B.M. Mulhern. 1979. Relations of Wintering Canvasbacks To Environmental Pollutants-Cheasapeake Bay, Maryland. Wilson's Bulletin. 91(2):279-287.

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION

WATERFOWL INVESTIGATION

ATTACHMENT I

STUDY DESIGN CONSIDERATIONS

MultiTech

ATTACHMENT I
DESIGN CONSIDERATIONS
FOR SBC RI WATERFOWL INVESTIGATION

In planning the Waterfowl Investigation, the following questions were addressed:

- What are the potential contaminants?
- What are the known effects of these contaminants on wild animals, specifically waterfowl?
- Do the contaminants bioaccumulate?
- In what tissues do the contaminants concentrate--muscle, viscera, bone?
- What tissues are consumed by humans?
- Do seasonal phenomena, such as migration, affect the concentration of contaminants in tissue?
- Is a particular bird species a herbivore or carnivore?
- What are the major food species available?
- What is the source of contamination?
- What is the potential for human exposure to "heavy metals" (i.e., are the birds hunted, and if so, how much, and by how many persons)?

Table I-1 lists heavy metal elements identified as being potentially toxic to biological systems (EPA 1981; Torrey 1978; Newman 1980) and also lists those heavy metals that have been investigated or are planned for investigation in the southern Deer Lodge Valley (Cornish 1984; Phillips 1982; Hydrometrics 1983; MultiTech and Stiller and Associates 1984a). A review of this table indicates that trace elements potentially of concern for waterfowl at the Warm Springs Ponds include: arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), aluminum (Al), chromium (Cr), nickel (Ni), and selenium (Se).

Table I-2 lists documented responses of birds and mammals to acute and chronic exposure to selected air pollutant emission elements. Even though this table addresses effects for air emissions, not consumption, the body tissue response for some of the elements is the same. In addition to creating some physiological reponse, these metals also bioaccumulate. Table I-3 lists those elements identified by the USEPA (1981) as bioaccumulators.

Table I-4 lists the organs best suited for monitoring avian exposure to heavy metals. The organs listed are known to concentrate greater element burdens than other tissues. As seen in this table, not all elements of interest in the Silver Bow Creek Waterfowl Investigation have recommended tissue types for sampling.

TABLE I-1
ELEMENTS POTENTIALLY TOXIC
TO BIOLOGICAL SYSTEMS

	Toxics EPA 1981[a]	Mine/Smelter EPA 1981[b]	Cornish 1984[c]	Torrey 1978[d]	Phillips 1982[e]	Hydrometrics 1983 IV[f]	Newman 1980[g]	MultiTech and Stiller 1984
Al			●					
Ag								
As	●	●	●	●	●	●	●	●
Ba				●			●	
Be	●						●	
Bo	●						●	
Cd	●	●	●	●	●	●	●	●
Cl				●				
Cr	●	●		●			●	
Co	●	●						
Cu	●			●	●	●		●
Fe				●		●	●	●
Hg	●	●		●	●	●	●	
Mn			●	●		●	●	
Mo							●	
Ni	●			●			●	
P							●	
Pb	●	●	●	●	●	●	●	●
Sb	●							
Se	●			●			●	
Si								
Sn	●	●						
V	●						●	
Zn			●	●	●	●	●	●

Notes:

(a) Elements listed as potentially toxic
(b) Elements listed as common from mining and smelting operations.
(c) Elements of concern listed by Cornish (1984) for a soil study around the Washoe Smelter in Anaconda, MT.
(d) Listed potentially toxic.
(e) Elements tested for in fish tissue of the upper Clark Fork River.
(f) Water quality measurements of Silver Bow Creek.
(g) Listed as having an affect on wildlife.

TABLE I-2
DOCUMENTED RESPONSES OF BIRDS AND MAMMALS (DOMESTIC AND LABORATORY ANIMALS AND WILDLIFE) TO ACUTE AND CHRONIC EXPOSURE TO SELECTED AIR EMISSIONS

Responses	Selected Air Pollutants															
	As	Bd	Be	B	Cr	Cp	Fe	Pb	Mn	Hg	Mo	Ni	P	Se	V	Zn
Changes in Population Numbers	●				●											
Changes in Blood Chemistry or Physiology	●		●		⊙			●			◐	⊙			●	
Changes in Cellular Enzymes	◐		●				⊙							⊙		●
Changes in External Appearance	⊙	⊙						●			●		●			
Change in Population Distribution																
Change in in Death Rate (in free living animals)	●		●	⊙	●			●								
Change in Birth Rate	⊙							⊙								
Change in Growth Rate			●					●								
Change in Generic Resistance																
Abnormal Behavior	●	●	●	●		●		●	●	●	⊙		●	●	●	⊙
Physiological Changes Observed in Autopsy and Historical Analysis	●				●			●	⊙			⊙	●	●	●	●
Lowered Resistance to Natural Environmental Stress	●															
Residue Accumulation in Body Tissues	⊙		●	●	●	●	●	●	●	●	●		⊙	●	●	⊙
Tetragenic, Mutagenic, or Carcinogenic		⊙	●		●	●						●		●		

Source: Newman 1980.

TABLE I-3
POTENTIAL FOR BIOACCUMULATION OF TOXIC
TRACE ELEMENTS IN MAMMALS, BIRDS, AND FISH

Element	Potential for Bioaccumulation[a]	Warm Springs Ponds Interest
Antimony	Low	
Arsenic	Moderate	High
Beryllium	Low	
Boron	Low	
Cadmium	High	High
Chromium	Moderate	Moderate
Cobalt	Low	
Copper	High	High
Lead	High	High
Mercury	High	Low
Nickel	Moderate	Moderate
Selenium	Moderate	Moderate
Tin	Moderate	
Vanadium	Low	
Zinc	NL[b]	High

(a) Source: EPA 1981.
(b) NL = Not Listed.

TABLE I-4
AVIAN BODY TISSUE RECOMMENDED FOR BIOLOGICAL
MONITORING OF HEAVY METAL EXPOSURE

Element [a]	Tissue Type [b]				
	Feather	Liver	Kidney	Muscle	Bone
Aluminum	I	I	I	I	I
Arsenic	G	G	I	I	I
Cadmium	P	E	E	I	I
Chromium	I	I	I	I	I
Copper	G	G	I	I	I
Lead	E	I	I	I	E
Mercury	E	E	G	I	I
Nickel	I	I	G	I	I
Selenium	G	G	I	I	I
Zinc	I	I	I	I	I

(a) Of potential interest to Silver Bow Creek Remedial Investigation, see Table A-3.

(b) Source: EPA 1981;
P = Poor
G = Good
E = Excellent
I = Insufficient Data

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION

WATERFOWL INVESTIGATION

ATTACHMENT II

QA/QC DATA

MultiTech

TABLE II-1
QA/QC SUMMARY: ARSENIC IN WATERFOWL TISSUE

Analysts' Replicates

Laboratory #	RSA%/DSA%[a]	Date	Required Range
T010M-R	100	4-04-85	85-115 or
T020M-R	94	4-05-85	± MDL
T027M-R	98	4-05-85	
T038M-R	98	4-05-85	
T004L-R	106	4-08-85	
Q353-R	103	4-08-85	
Q356-R	93	4-09-85	

Analysts' Calibration Checks

Laboratory #	KSA%[b]	Date	Required Range
WP1178#1	107	4-04-85	85-115 or
WP1178#1	106	4-05-85	± MDL
WP1178#1	97	4-05-85	
WP1178#1	92	4-05-85	
WP1178#1	91	4-08-85	
WP1178#1	104	4-08-85	
WP1178#1	108	4-09-85	

Analysts' Spikes

Laboratory #	SSR%[f]	Date	Required Range
T003M-S	98	4-04-85	75-125
T015M-S	88	4-05-85	
T033M-S	78	4-05-85	
T001L-S	94	4-05-85	
Q353-S	74	4-08-85	
Q349-S	90	4-08-85	
Q355-S	80	4-09-85	

Sample Bank Standards

Laboratory #	KSA%[b]	Date
Q353[c]	86	4-08-85
Q354[c]	106	4-08-85
Q361	[d]	4-09-85
Q362	[d]	4-09-85

Sample Bank Spikes

Laboratory #	SSR%	Date
Q355[e]	88	4-09-85
Q555[e]	109	4-09-85

Sample Bank Blanks

Laboratory #	Value	Date
Q349	<4.1 µg/L	4-08-85
Q350	<4.1 µg/L	4-08-85
Q351	<4.1 µg/L	4-08-85
Q352	<4.1 µg/L	4-08-85

Sample Bank Duplicates

Laboratory #	DSA%[a]	Date
Q357[g]	81	4-09-85
Q358[g]	125	4-09-85
Q359[g]	91	4-09-85
Q360[g]	70	4-09-85
Q363[h]	64	4-09-85
Q364[h]	61	4-09-85

[a] DSA% and RSA% = $\frac{M_2}{(M_1+M_2)/2} * 100$

[b] KSA% = $\frac{\text{measured value}}{\text{true value}} * 100$

[c] USEPA standard.

[d] NBS Bovine Liver Standard. True value less than MDL.

[e] Predigestion spikes.

[f] SSR% = $\frac{(\text{spiked sample}) - (\text{sample})\ (\text{dilution factor})}{(\text{spike})\ (\text{dilution factor})} * 100$

[g] Tissue splits. <DL used at DL value.

[h] Digestion solution splits. <DL used at DL value.

TABLE II-2
QA/QC SUMMARY: CADMIUM IN WATERFOWL TISSUE

Analysts' Replicates

Laboratory #	RSA%/DSA%[a]	Date	Required Range
T007M-R	90	4-10-85	90-110 or
T014M-R	99	4-11-85	± MDL
T028M-R	91	4-11-85	
T036M-R	106	4-11-85	
T002L-R	102	4-11-85	
Q360-R	105	4-12-85	

Sample Bank Standards

Laboratory #	KSA%[b]	Date
Q353[c]	115	4-11-85
Q354[c]	77	4-11-85
Q361[d]	18	4-12-85
Q362[d]	33	4-12-85
Q361[d]	73	9-06-85
Q362[d]	92	9-06-85
Q354[c]	98	9-06-85

Sample Bank Spikes

Laboratory #	SSR%[e]	Date
Q355	[f]	4-12-85
Q356	[f]	4-12-85

Analysts' Calibration Checks

Laboratory #	KSA%[b]	Date	Required Range
10ppb	94	4-10-85	90-110 or
10ppb	110	4-11-85	± MDL
10ppb	91	4-11-85	
10ppb	99	4-11-85	
10ppb	94	4-11-85	
10ppb	93	4-12-85	

Sample Bank Blanks

Laboratory #	Value	Date
Q349	2.4 µg/L	4-08-85
Q350	1.3 µg/L	4-08-85
Q351	3.4 µg/L	4-08-85
Q352	<1.2 µg/L	4-08-85
Q349	3.2 µg/L	9-06-85
Q350	2.2 µg/L	9-06-85

Analysts' Spikes

Laboratory #	SSR%[e]	Date	Required Range
T005M-S	90	4-10-85	75-125
T018M-S	116	4-11-85	
T033M-S	123	4-11-85	
T036M-S	85	4-11-85	
Q353-S	98	4-11-85	
Q357-S	102	4-12-85	

Sample Bank Duplicates

Laboratory #	DSA%[a]	Date
Q357[g]	65	4-12-85
Q358[g]	94	4-12-85
Q359[g]	35	4-12-85
Q360[g]	105	4-12-85
Q363[h]	100	4-12-85
Q364[h]	100	4-12-85
Q359[g]	48	9-06-85

[a] DSA% and RSA% = $\frac{M_2}{(M_1+M_2)/2} * 100$

[b] KSA% = $\frac{\text{measured value}}{\text{true value}} * 100$

[c] USEPA standard.

[d] NBS Bovine Liver Standard. True value less than MDL.

[e] SSR% = $\frac{(\text{spiked sample}) - (\text{Sample})\ (\text{dilution factor})}{(\text{spike})\ (\text{dilution factor})} * 100$

[f] Predigestion spikes. Spiked at less than 50% of sample.

[g] Tissue splits. <DL used at DL value.

[h] Digestion solution splits. <DL used at DL value.

TABLE II-3
QA/QC SUMMARY: COPPER IN WATERFOWL TISSUE

Analysts' Replicates

Laboratory #	RSA%/DSA%[a]	Date	Required Range
T004M-R	103	4-04-85	85-115 or
T017M-R	96	4-04-85	± MDL
T029M-R	97	4-04-85	
T036M-R	102	4-04-85	
T044M-R	108	4-04-85	
Q357-R	106	4-04-85	
Q361-R	98	4-04-85	

Analysts' Calibration Checks

Laboratory #	KSA%[b]	Date	Required Range
WP475#3	92	4-04-85	85-115 or
WP475#3	97	4-04-85	± MDL
WP475#3	97	4-04-85	
WP475#3	96	4-04-85	
WP475#3	100	4-04-85	
WP475#3	97	4-04-85	
WP475#3	100	4-04-85	
WP475#3	94	4-04-85	

Analysts' Spikes

Laboratory #	SSR%[e]	Date	Required Range
T002M-S	94	4-04-85	75-125
T011M-S	86	4-04-85	
T022M-S	89	4-04-85	
T037M-S	92	4-04-85	
T002L-S	89	4-04-85	
Q355-S	106	4-04-85	
Q362-S	86	4-04-85	

Sample Bank Standards

Laboratory #	KSA%[b]	Date
Q353[c]	91	4-04-85
Q354[c]	92	4-04-85
Q361[d]	92	4-04-85
Q362[d]	92	4-04-85

Sample Bank Spikes

Laboratory #	SSR%[e]	Date
Q355[f]	(g)	4-04-85
Q356[f]	(h)	4-04-85

Sample Bank Blanks

Laboratory #	Value	Date
Q349	<67 µg/L	4-04-85
Q350	<67 µg/L	4-04-85
Q351	<67 µg/L	4-04-85
Q352	<67 µg/L	4-04-85

Sample Bank Duplicates

Laboratory #	DSA%[a]	Date
Q357[i]	86	4-04-85
Q358[i]	93	4-04-85
Q359[i]	95	4-04-85
Q360[i]	93	4-04-85
Q363[i]	103	4-04-85
Q364[j]	96	4-04-85

(a) DSA% and RSA% = $\frac{M_2}{(M_1+M_2)/2} * 100$

(b) KSA% = $\frac{\text{measured value}}{\text{true value}} * 100$

(c) USEPA standard.

(d) NBS Bovine Liver.

(e) SSR% = $\frac{\text{(spiked sample) - (Sample) (dilution factor)}}{\text{(spike) (dilution factor)}} * 100$

(f) Predigestion spikes.

(g) Spiked at 15% of sample.

(h) Spiked at 17% of sample.

(i) Tissue splits.

(j) Digestion solution splits.

TABLE II-4
QA/QC SUMMARY: ZINC IN WATERFOWL TISSUE

Analysts' Replicates

Laboratory #	RSA%/DSA%[a]	Date	Required Range
T004M-R	100	4-04-85	85-115 or
T017M-R	95	4-04-85	± MDL
T029M-R	98	4-04-85	
T036M-R	100	4-04-85	
T044M-R	108	4-04-85	
Q357-R	104	4-04-85	
Q361-R	98	4-04-85	

Analysts' Calibration Checks

Laboratory #	KSA%[b]	Date	Required Range
WP475#3	102	4-04-85	85-115 or
WP475#3	106	4-04-85	± MDL
WP475#3	105	4-04-85	
WP475#3	101	4-04-85	
WP475#3	106	4-04-85	
WP475#3	104	4-04-85	
WP475#3	108	4-04-85	
WP475#3	99	4-04-85	

Analysts' Spikes

Laboratory #	SSR%[e]	Date	Required Range
T002M-S	104	4-04-85	75-125
T011M-S	87	4-04-85	
T022M-S	95	4-04-85	
T037M-S	103	4-04-85	
T002L-S	124	4-04-85	
Q355-S	113	4-04-85	
Q362-S	79	4-04-85	

Sample Bank Standards

Laboratory #	KSA%[b]	Date
Q353[c]	102	4-04-85
Q354[c]	100	4-04-85
Q361[d]	100	4-04-85
Q362[d]	100	4-04-85

Sample Bank Spikes

Laboratory #	SSR%[e]	Date
Q355[f]	(g)	4-04-85
Q356[f]	(h)	4-04-85

Sample Bank Blanks

Laboratory #	Value	Date
Q349	<15 µg/L	4-04-85
Q350	23 µg/L	4-04-85
Q351	<15 µg/L	4-04-85
Q352	<15 µg/L	4-04-85

Sample Bank Duplicates

Laboratory #	DSA%[a]	Date
Q357[i]	90	4-04-85
Q358[i]	101	4-04-85
Q359[i]	95	4-04-85
Q360[i]	102	4-04-85
Q363[j]	105	4-04-85
Q364[j]	102	4-04-85

(a) DSA% and RSA% = $\frac{M_2}{(M_1+M_2)/2} * 100$

(b) KSA% = $\frac{\text{measured value}}{\text{true value}} * 100$

(c) USEPA standard.

(d) NBS Bovine Liver.

(e) SSR% = $\frac{\text{(spiked sample) - (Sample) (dilution factor)}}{\text{(spike) (dilution factor)}} * 100$

(f) Predigestion spikes.

(g) Spiked at 18% of sample.

(h) Spiked at 10% of sample.

(i) Tissue splits.

(j) Digestion solution splits.

TABLE II-5
QA/QC NOTES FOR PCP AND PCB ANALYSES

PCP

	Lab No.	Value
PCP Sample Bank Blank	Q970	<.005 ppm
PCP Samples Bank Duplicate	Q972	DSA% = 114(a)
PCP Sample Bank Standard	Q974	KSA% = 35%(b)

Internal QA/QC sample data available in files of contract laboratory.

PCB

	Lab No.	Value
PCB Sample Bank Blank	Q971	<.004 mg/sample
PCB Sample Bank Duplicate	Q973	Whole Tissue DSA% = 54%(a) Lipid based DSA% = 98%(a)
PCB Sample Bank Standard	Q975	KSA% = 69%(b)

(a) $DSA\% = \frac{M_2}{(M_1+M_2)/2} * 100$

(b) $KSA\% = \frac{\text{measured value}}{\text{true value}} * 100$

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION

WATERFOWL INVESTIGATION

ATTACHMENT III

LITERATURE EXAMPLES OF CONTAMINANT CONCENTRATIONS IN WATERFOWL TISSUE

MultiTech

TABLE III-1
ARSENIC IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Turner, et al. 1978	New Zealand	Black-backed gull (Larus dominicanus)/Liver	Life Span	N.G.	N=34, .44($\bar{x}$)[c] ±.23(SD)[d]
Turner, et al. 1978	New Zealand	Red-billed gull (Laurus novaeholl-andiae scopulinus)/ Liver	Life Span	N.G.	N=29, .42($\bar{x}$)[e] ± 22(SD)[f]
Turner, et al. 1978	New Zealand	South Island Pied oyster catcher (Haematopus ostra-legus finschi)/Liver	Life Span	N.G.	N=16, 1.12($\bar{x}$)[g] ±.99(SD)[h]
Turner, et al. 1978	New Zealand	Pied Stilt (Himantopus himantopus leucoce-phalus/Liver	Life Span	N.G.	N=27, .63($\bar{x}$)[c] ±.45(SD)[d]
Turner, et al. 1978	New Zealand	Pukeko (Porphyrio porphyrio melanotus)/ Liver	Life Span	N.G.	N=24, .21($\bar{x}$)[g] ±.12(SD)[h]
Greichus, et al. 1978	Lake McIlwaine, Rhodesia	White-breasted cormorant (Phalacroco-rax carbo lucidus)/ Whole carcass less GI tract contents, brain, and 10 g of feathers.	Life Span	Water n=3, .003(x) Sediment n=3, 37.0(x)[h]	N=3, 1.4($\bar{x}$)[i]

[a] N.G. = Not given.
[b] Wet weight.
[c] Mean of 6 means.
[d] SD of 6 means.
[e] Mean of 7 means.
[f] Standard Deviation (SD) of 7 means.
[g] Mean of 4 means.
[h] Standard Deviation (SD) of 4 means.
[i] Dry weight.

TABLE III-2

CADMIUM IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE

Citation	Location	Species/Tissue	Exposure	Water conc. (ppm)[a]	Sediment	Tissue Conc. µg/g(ppm)[b]
White, et al. 1979	Cheasapeake Bay, Maryland	Canvasback (Aythya valisneria/Liver	Life Span	N.G.		N=29, .59($\bar{x}$)[c]±.09(SE)[d]
Maedgen, et al. 1982	Galveston Bay, Texas	Royal Tern (Thalasseus maximus/Muscle	Life Span	N.G.	Downy Young: Prefledglings: Adult:	N=5,.017($\bar{x}$)±.006(SD) N=5,.014($\bar{x}$)±.003(SD) N=9,.075(x)±.050(SD)
Maedgen, et al. 1982	Galveston Bay, Texas	Royal Term (Thalasseus maximus)/Muscle	Life Span	N.G.	Downy Young: Prefledglings: Adult:	N=5,.008($\bar{x}$)± .004(SD) N=5,.011(x)± .004(SD) N=9,1.185(x)± .582(SD)
White and Finley 1978	Lab	Mallard (Anas platyrynchos)/Muscle	30 days 60 days 90 days 30 days post.	control control control control		N=10,.122($\bar{x}$)±.016(SE) N=10,.391($\bar{x}$)±.107(SE)
Nicholson 1981	North Atlantic	Herring Gull (Larus argentatus)/Muscle	Life Span	N.G.		N=10 <.25
Nicholson 1981	North Atlantic	Herring Gull (Larus argentatus)/Liver	Life Span	N.G.		N=11 <1.86($\bar{x}$)±.25(SE) Range <.25-3.9
Bull, et al. 1977	North Atlantic	Fulmar (fulmarus glacialis), Manx shearwater (Puffinus puffinus), Puffin Fratercula arctica), Leach's petrel (Oceanodromo leucorhoa), storm petrel, Hydrobates pelagicus), Razorbill (Alca torda)/Liver	Life Span	N.G.		N=21, Range, 1.4 - 57.0

TABLE III-2
CADMIUM IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Anderlini et al. 1972.	California (Pacific breeding island)	Ashy petrel (Oceanodroma homochroa)/Liver	Life Span	N.G.	N=10, 53.2($\bar{x}$)±.20.5
Stoneburner, et al. 1980	Dry Tortugas, Florida	Sooty Tern (Sterna fuscata)/ Muscle	Life Span	N.G.	N=12, 1.11($\bar{x}$)±.06(SE)
Stoneburner, et al. 1980	Dry Tortugas, Florida	Sooty Tern (Sterna fuscata)/ Liver	Life Span	N.G.	N=12, 3.79($\bar{x}$)±.36(SE)
Furness and Hutton 1980	North Atlantic	Great skuas (Catharacta skua)/Liver	Life Span	N.G.	N=12, 1.4($\bar{x}$) Range .3-3.1
Blus, et al. 1977	South Carolina	Brown pelican (Pelecanus occidentalis)/ Liver	Life Span	N.G.	N=8, .01-1.06
Turner, et al. 1978	New Zealand	Black-backed gull (Larus dominicanus)/ Liver	Life Span	N.G.	N=34, .62($\bar{x}$)[c]±.14(SD)[e]
Turner, et al. 1978	New Zealand	Red-billed gull (Larus novaeholl-andiae scopulinus)/ Liver	Life Span	N.G.	N=29, .92($\bar{x}$)[f]±.41(SD)[g]
Turner, et al. 1978	New Zealand	South Island Pied oyster catcher (Haematopus ostralegus finschi)/ Liver	Life Span	N.G.	N=16, .65($\bar{x}$)[h]±.11(SD)[i]

TABLE III-2
CADMIUM IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Turner, et al. 1978	New Zealand	Pied Stilt (Himan topus himantopus leuco cepholus)/Liver	Life Span	N.G.	N=23, $\bar{x}$[c] ± .16(SD)[e]
Turner, et al. 1978	New Zealand	Pukeko (Porphyrio porphyrio melanotus)/ Liver	Life Span	N.G.	N=27, $\bar{x}$[c] ± .19(SD)[e]
Hulse, et al. 1978	Galveston Bay, Texas	Cattle egret (Bubulcus ibis)/ Muscle	Life Span	N.G.	Downy Young: N=11, $\bar{x}$ ± SE = .093 ± .030 Range: .018 - .292 Prefledgings: N=6, $\bar{x}$ ± SE = .027 ± .004 Range: .017 - .040 Adult: N=8, $\bar{x}$ ± SE = .025 ± .005
Hulse, et al. 1978	Galveston Bay, Texas	Cattle egret (Bubulcus ibis)/ Muscle	Life Span	N.G.	Downy Young: N=11, $\bar{x}$ ± SE = .056 ± .008 Range: .030 - .106 Prefledgings: N=6, $\bar{x}$ ± SE = .029 ± .004 Range: .019 - .046 Adult: N=9, $\bar{x}$ ± SE = .115 ± .016 Range: .019 - .206
Hulse, et al. 1978	Galveston Bay, Texas	Laughing gull (Larus atricilla)/ Muscle	Life Span	N.G.	Downy Young: N=10, $\bar{x}$ ± SE = .013 ± .005 Range: <.001 - .048 Prefledgings: N=10, <.001 Range: 0 - <.0014 Adult: N=25, $\bar{x}$ ± SE = .054 ± .009 Range: .005 - .109
Hulse, et al. 1980	Galveston Bay, Texas	Laughing gull (Larus atricilla)/ Liver	Life Span	N.G.	Downy Young: N=10, $\bar{x}$ ± SE = .009 ± .004 Range: <.001 - .045 Prefledgings: N=10, $\bar{x}$ ± SE = .116 ± .064 Range: .015 - .691 Adult: N=25, $\bar{x}$ ± SE = .220 ± .025 Range: .079 - .579

TABLE III-2
CADMIUM IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Greichus, et al. 1978	Lake McIlwaine, Rhodesia	White-breasted cormorant (Phalacrocorax carbo lucidus)/Whole carcass less GI tract contents, brain, and 10g of feathers	Life Span	Water: N=3, .001(x) Sediment: N=3, .39(x)	N=3, .04($\bar{x}$)[j]

[a] N.G. = Not given.
[b] Wet weight.
[c] Mean of 6 means.
[d] SE = Standard error.
[e] Standard Deviation (SD) of 6 means.
[f] Mean of 7 means.
[g] Standard Deviation of 7 means.
[h] Mean of 4 means.
[i] Standard Deviation of 4 means.
[j] Dry weight.

TABLE III-3
COPPER IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
White, et al. 1979	Cheasapeake Bay	Canvasbacks (Aythya valisineria) /Liver	Life Span	N.G.	N=29, $59(\bar{x})\pm 8(SE)$[c]
Blus, et al. 1977	South Carolina	Brown Pelican Pelecanus occidentalis)/Liver	Life Span	N.G.	N=8, 4.3 - 9.0
Turner, et al. 1978	New Zealand	Black-backed gull (Larus dominicanus)/ Liver	Life Span	N.G.	N=34, $5.89(\bar{\bar{x}})$[d] $\pm 3(SD)$[e]
Turner, et al. 1978	New Zealand	Red-billed gull (Larus novaehollandiae scopulinus/ Liver	Life Span	N.G.	N=103, $5.52(\bar{\bar{x}})$[f] $\pm 1.25(SD)$[g]
Turner, et al. 1978	New Zealand	South Island Pied Oyster catcher (Haematopus ostralegus finschi)/ Liver	Life Span	N.G.	N=16, $3.39(\bar{\bar{x}})$[h] $\pm .33(SD)$[i]
Turner et al. 1978	New Zealand	Pied Stilt (Himantopus leucocepholus)/ Liver	Life Span	N.G.	N=23, $9.77(\bar{\bar{x}})$[d] $9.39(SD)$[e]

TABLE III-3
COPPER IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Turner et al. 1978	New Zealand	Pukeko (Porphyrio porphyrio melanotus)/ Liver	Life Span	N.G.	N=28, 4.04($\bar{x}$)[d] ±1.16(SD)[e]
Greichus, et al. 1978	Lake McIlwaine, Rhodesia	White-breasted cormorant (Phalacrocorax lucidus)/ whole carcass less GI tract contents, brain, and 10 g of feathers.	Life Span	water: n=3, .010(x) sediment: n=3, 38(x)	N=3, 3.1($\bar{x}$)[j]

[a] N.G. = Not given.
[b] Wet weight.
[c] SE = Standard Error.
[d] Mean of 6 means.
[e] Standard Deviation SD of 6 means.
[f] Mean of 7 means.
[g] Standard Deviation of 7 means.
[h] Mean of 4 means.
[i] Standard Deviation of 4 means.
[j] Dry weight.

TABLE III-4
ZINC IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
White, et al. 1979.	Cheasapeake Bay	Canvasbacks (Aythya valisineria/Liver	Life Span	N.G.	N=29, 41($\bar{x}$)±3(SE)[c]
Nicholson 1981	North Atlantic	Herring Gull (Larus argentatus)/ Muscle	Life Span	N.G.	N=10, 58.7(x)±2.9(SE)
Nicholson 1981	North Atlantic	Herring Gull (Larus Argentatus)/ Liver	Life Span	N.G.	N=11, 66.6($\bar{x}$)±3.0(SE)
Blus, et al. 1977	South Carolina	Brown pelican (Pelecanus occidentalis)/Liver	Life Span	N.G.	N=8, 26-55
Turner, et al. 1978	New Zealand	Black-backed Gull (Larus dominicus)/ Liver	Life Span	N.G.	N=34,32.9($\bar{\bar{x}}$)[d]±9.49(SD)[e]
Turner et al. 1978	New Zealand	Red-billed Gull (Larus novaeholl-andiae)/Liver	Life Span	N.G.	N=29,30.4($\bar{\bar{x}}$)[f]±7.04(SD)[g]
Turner, et al. 1978	New Zealand	South Island Pied oyster catcher (Haematopus ostralegus finschi)/ Liver	Life Span	N.G.	N=16,31.7($\bar{\bar{x}}$)[h]±5.91(SD)[i]

TABLE III-4
ZINC IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Water Sediment conc. (ppm)[a]	Tissue Conc. µg/g(ppm)[b]
Turner, et al. 1978	New Zealand	Pied stilt (Himantopas himantopus leucocephalus)/ Liver	Life Span	N.G.	N=23, 44.3($\bar{x}$)[d] ± 23.2(SD)[e]
Turner, et al. 1978	New Zealand	Pukeko (Porphyrio porphyrio melanotus)/ Liver	Life Span	N.G.	N=28, 27.5($\bar{x}$)[d] ±6.05(SD)[e]
Greichus, et al. 1978.	Lake McIlwaine, Rhodesia	White-breasted cormorant (Phalcrocorax carbo lucidus)/ whole carcass less GI tract contents, brain, and 10 g feathers	Life Span	Water: n=3, .012($\bar{x}$) Sediment: n=3, 100($\bar{x}$)	N=3, 77.($\bar{x}$)[j]

[a] N.G. = Not given.
[b] Wet weight.
[c] SE = Standard Error.
[d] Mean of 6 means.
[e] Standard Deviation (SD) of 6 means.
[f] Mean of 7 means.
[g] Standard Deviation of 7 means.
[h] Mean of 4 means.
[i] Standard Deviation of 4 means.
[j] Dry weight.

TABLE III-5
PCB IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE

Citation	Location	Species/Tissue	Exposure	Tissue Conc. µg/g(ppm)[a]
White, et al. 1979	Cheasapeake Bay, Maryland	Canvasbacks (Aythya valisineria)/ Whole carcass (less feathers, beaks, feet, and GI tract)	Life Span	1973:N=18, 1.5($\bar{x}$)+ .31(SE)[b] 1975:N=112, 2.7(x)+ .21(SE)
Furness and Hutton 1980	North Atlantic	Great skua (Catharacta skua)/ Muscle	Life Span	Shetland: N=5, 15.9 (GM)[c] Range: 10.2 - 32.0 Iceland: N=10, 16.0 (GM) Range: 5.3 - 47.0
Blus, et al. 1977	South Carolina, Georgia, Florida	Brown Pelican (Pelecanus occidentalis)/Whole carcass (less skin, feet, wings, liver, kidney, and G.I. tract)	Life Span	1971-1973:N=12, 6.7($\bar{x}$)+7.3(SD)
Turner, et al. 1978	New Zealand	Black-backed gull (Larus dominicanus)/ Muscle	Life Span	Auckland: N=6, .92($\bar{x}$) Tauranga: N=5, .58($\bar{x}$) Hutt Valley: N=2, .96($\bar{x}$) Hokitika: N=8, .08($\bar{x}$) Christchurch: N=8, .98($\bar{x}$) Bluff: N=5, .21(x) $\bar{\bar{x}}$= .62 $SD_{\bar{x}}$=.40

TABLE III-5
PCB IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Tissue Conc. µg/g(ppm)(a)
Turner, et al. 1978	New Zealand	Red-billed gull (Larus novaeholl-andiae scopulinus)/ Muscle	Life Span	Auckland: N=8, .32($\bar{x}$) Tauranga: N=6, .26($\bar{x}$) Pautahanui: N=3,2.87(x) Hut Valley: N=1,1.42 Hokitika: N=2, .43($\bar{x}$) Christchurch: N=8, .46($\bar{x}$) Bluff: N=2, .05(x) $\bar{\bar{x}}$= .83 $SD_{\bar{\bar{x}}}$=1.0
Turner, et al. 1978	New Zealand	South Island Pied Oyster catcher (Haematopus ostralegus finschi)/muscle	Life Span	Auckland: N=5, .12($\bar{x}$) Christchurch: N=6, .19(x) $\bar{\bar{x}}$= .15 $SD_{\bar{\bar{x}}}$=.05
Turner, et al. 1978	New Zealand	Pied Stilt (Himantopus himantopus leucocephalus)/ Muscle		Auckland: N=8, .07($\bar{x}$) Taurango: N=8, .03($\bar{x}$) Bluff: N=4, .03(x) $\bar{\bar{x}}$= .04 $SD_{\bar{\bar{x}}}$=.02
Turner, et al. 1978	New Zealand	Pukeko (Porphyrio porphyrio melanotus/ Muscle		Auckland: N=7, .05($\bar{x}$) Christchurch: N=8, .02(x) $\bar{\bar{x}}$= .03 $SD_{\bar{\bar{x}}}$ .02

TABLE III-5
PCB IN WATERFOWL TISSUE - EXAMPLES FROM THE LITERATURE (Cont.)

Citation	Location	Species/Tissue	Exposure	Tissue Conc. µg/g(ppm)[a]
Greichus et al. 1978	Lake McIlwaine, Rhodesia	White-breasted cormorant (Phalacrocorax carbo lucidus)/ Whole carcass less GI Tract contents, brain, and 10 g feathers	Life Span	N=10: A1254, 9.8[d] A1260, 3.7[d]
Peterson and Ellarson 1978	Lake Michigan	Oldsquaw (Claugula hyemalis)/ whole carcass	Life Span	4-107 Concentration factor for food →duck ranged from 1-22.
Custer and Heinz 1980.	Lab	Mallard (Anas platyrhynchos)/Whole carcass less feathers, bills, feet, wingtips and GI tracts.	various	male, controls: N=5, .01($\bar{x}$) male, 25 ppm diet: N=10 4.0($\bar{x}$) female, controls: N=5 .01($\bar{x}$) female, 25 ppm diet: N=10 1.9(x)

[a]Wet weight.
[b]SE = Standard error.
[c]GM = Geometric mean.
[d]Dry weight.

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION

WATERFOWL INVESTIGATION

ATTACHMENT IV

STATISTICAL SUMMARIES

MultiTech

TABLE IV-1

ARSENIC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO ARSENIC IN MUSCLE TISSUE OF CONTROL SAMPLES.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% of Erroneously Rejecting H_o(c)
<DL @ DL:	W.S.P.	C	.160	37	.233	.068	4	.009	.789	43
<DL @ 1/2 DL:	W.S.P	C	.096	37	.119	.034	4	.005	1.03	31
<DL @ 1/2 DL, (Log x)(-1):	W.S.P.	C	1.23	37	.422	1.47	4	.006	1.10	27

(a)W.S.P. = Warm Springs Ponds.
(b)C = Control.
(c)H_o = No Difference in means.

TABLE IV-2

ARSENIC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO ARSENIC IN WARM SPRINGS PONDS WATERFOWL LIVER TISSUE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Mus.	L	.160	37	.233	.066	5	.028	.90	38
<DL @ 1/2 DL:	Mus.	L	.091	37	.119	.061	5	.032	.70	51
<DL @ 1/2 DL, (Log x)(-1):	Mus.	L	1.23	37	.422	1.20	5	.169	-.15	88

(a) Mus. = Muscle.
(b) L = Liver.
(c) H_o = No Difference in means.

TABLE IV-3

ARSENIC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY AGE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	A	J	.044	13	.009	.223	24	.270	-2.37	2
<DL @ 1/2 DL:	A	J	.025	13	.012	.135	24	.133	-2.96	1
<DL @ 1/2 DL, (Log x)(-1):	A	J	1.64	13	.148	1.02	24	.358	5.93	ø

(1) A = Adult.
(2) J = Juvenile.
(3) H_o = No Difference in means.

TABLE IV-4

ARSENIC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SEX.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values are in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	M	F	.045	11	.010	.040	2	.0028	.69	50
<DL @ 1/2 DL:	M	F	.026	11	.013	.020	2	.0014	.28	57
<DL @ 1/2 DL, (Log x)(-1):	M	F	1.62	11	.159	1.69	2	.037	-.64	53
<DL @ DL:	M	S U	.045	11	.010	.223	24	.270	-2.17	4
<DL @ 1/2 DL:	M	S U	.026	11	.013	.135	24	.133	-2.69	1
<DL @ 1/2 DL, (Log x)(-1):	M	S U	1.62	11	.159	1.02	24	.358	5.35	0
<DL @ DL:	F	S U	.040	2	.0028	.223	24	.270	-.94	35
<DL @ 1/2 DL:	F	S U	.020	2	.0014	.135	24	.133	-1.20	24
<DL @ 1/2 DL, (Log x)(-1):	F	S U	1.69	2	.037	1.02	24	.358	-2.64	1

(a)M = Male, F = Female.
(b)SU = Sex Unknown.
(c)H_o = No Difference in means.

TABLE IV-5

ARSENIC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SUBFAMILY.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Ana.	Ayt.	.099	17	.091	.277	14	.341	-2.06	5
<DL @ 1/2 DL:	Ana.	Ayt.	.070	17	.053	.149	14	.175	-1.76	9
<DL @ 1/2 DL, (Log x)(-1):	Ana.	Ayt.	1.29	17	.368	1.11	14	.530	1.12	27
<DL @ DL:	Ana.	Ans.	.099	17	.091	.061	6	.010	1.02	31
<DL @ 1/2 DL:	Ana.	Ans.	.070	17	.053	.047	6	.022	.99	33
<DL @ 1/2 DL, (Log x)(-1):	Ana.	Ans.	1.29	17	.368	1.36	6	.211	-.46	65
<DL @ DL:	Ayt.	Ans.	.277	14	.341	.061	6	.010	1.53	14
<DL @ 1/2 DL:	Ayt.	Ans.	.149	14	.175	.047	6	.022	1.39	18
<DL @ 1/2 DL, (Log x)(-1):	Ayt.	Ans.	1.11	14	.530	1.36	6	.211	1.13	27

(a)Ana. = Anatinae, Ayt. = Aythyinae.
(b)Ans. = Anserinae.
(c)H_o = No Difference in means.

TABLE IV-6

CORRELATION TESTS FOR ARSENIC IN WARM SPRINGS PONDS WATERFOWL TISSUE.

Independent variables (X and Y), number of pairs (N), and coefficient of determination (r^2) are presented for each test for <DL reported at the DL, for <DL reported at 1/2 the DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1).

			r^2 (a)		
X	Y	N	<DL@ DL	<DL@ 1/2 DL	<DL@ 1/2 DL, Transformed
Body Weight	As in Liver	5	.33	.19	.38
Body Weight	As in Muscle	37	.24	.24	.25
As in Muscle	Cd in Muscle	37	.68	.69	.26
As in Muscle	Zn in Muscle	37	.38	.39	.30
As in Muscle	Cu in Muscle	37	.14	<.10	<.10
As in Liver	Cd in Liver	5	<.10	<.10	.13
As in Liver	Zn in Liver	5	<.10	.18	.14
As in Liver	Cu in Liver	5	.92	.97	.87

(a)Using linear equation.

TABLE IV-7

CADMIUM IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO CADMIUM IN MUSCLE TISSUE OF CONTROL SAMPLES COLLECTED OFFSITE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	W.S.P.	C	.124	37	.232	.078	4	.078	.395	70
<DL @ 1/2 DL:	W.S.P.	C	.121	37	.233	.075	4	.081	.386	70
<DL @ 1/2 DL, (Log x)(-1):	W.S.P.	C	1.36	37	.618	1.52	4	.786	.487	63

[a] W.S.P. = Warm Springs Ponds.
[b] C = Control.
[c] H_o = No Difference in means.

TABLE IV-8

CADMIUM IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO CADMIUM IN LIVER TISSUE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Mus.	L	.124	37	.232	2.34	5	1.39	-9.42	<1
<DL @ 1/2 DL:	Mus.	L	.120	37	.233	2.34	5	1.39	-9.43	<1
<DL @ 1/2 DL, (Log x)(-1):	Mus.	L	1.36	37	.618	-.314	5	.236	-5.94	<1

[a] Mus. = Muscle.
[b] L = Liver.
[c] H_o = No Difference in means.

TABLE IV-9

CADMIUM IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY AGE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	A	J	.042	13	.046	.169	24	.279	-1.62	11
<DL @ 1/2 DL:	A	J	.040	13	.034	.164	24	.281	-1.58	13
<DL @ 1/2 DL, (Log x)(-1):	A	J	1.60	13	.476	1.23	24	.656	1.77	9

(a)A = Adult.
(b)J = Juvenile.
(c)H_o = No Difference in means.

TABLE IV-10

CADMIUM IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SEX.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	M	F	.038	11	.032	.070	2	.020	-1.33	21
<DL @ 1/2 DL:	M	F	.035	11	.034	.069	2	.020	-1.34	21
<DL @ 1/2 DL, (Log x)(-1):	M	F	1.67	11	.475	1.16	2	.130	1.45	17
<DL @ DL:	M	S U	.038	11	.032	.170	24	.280	-1.55	13
<DL @ 1/2 DL:	M	S U	.035	11	.034	.164	24	.281	-1.51	14
<DL @ 1/2 DL, (Log x)(-1):	M	S U	1.67	11	.475	1.23	24	.656	2.01	5
<DL @ DL:	F	S U	.070	2	.020	.170	24	.280	-.49	63
<DL @ 1/2 DL:	F	S U	.069	2	.020	.164	24	.281	-.47	64
<DL @ 1/2 DL, (Log x)(-1):	F	S U	1.16	2	.130	1.23	24	.656	.13	89

(a)F = Female, M = Male.
(b)SU = Sex Unknown.
(c)H_o = No Difference in means.

TABLE IV-11

CADMIUM IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SUBFAMILY.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1). All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Ana.	Ayt.	.049	17	.077	.238	14	.341	-2.22	3
<DL @ 1/2 DL:	Ana.	Ayt.	.047	17	.078	.236	14	.344	-2.16	4
<DL @ 1/2 DL, (Log x)(-1):	Ana.	Ayt.	1.68	17	.522	.930	14	.484	4.12	<1
<DL @ DL:	Ana.	Ans.	.049	17	.077	.073	6	.086	-.651	52
<DL @ 1/2 DL:	Ana.	Ans.	.047	17	.078	.072	6	.088	-.645	52
<DL @ 1/2 DL, (Log x)(-1):	Ana.	Ans.	1.68	17	.522	1.45	6	.622	.872	39
<DL @ DL:	Ayt.	Ans.	.238	14	.341	.073	6	.086	1.15	27
<DL @ 1/2 DL:	Ayt.	Ans.	.232	14	.344	.072	6	.088	1.11	28
<DL @ 1/2 DL, (Log x)(-1):	Ayt.	Ans.	.930	14	.484	1.45	6	.622	2.05	6

[a]Ana. = Anatinae, Ayt. = Aythinae.
[b]Ans. = Anserinae.
[c]H_o = No Difference in means.

TABLE IV-12

CORRELATION TESTS FOR CADMIUM IN WARM SPRINGS PONDS WATERFOWL TISSUE.

Independent variables (x and y), number of pairs (N), and coefficient of determination (r^2) are presented for each test for <DL reported at the DL, for <DL reported at 1/2 the DL, and for <DL reported at 1/2 DL and transformed by (log x)(-1).

X	Y	N	r^2 (a) <DL@ DL	<DL@ 1/2 DL	<DL@ 1/2 DL, Transformed
Body Weight	As in Liver	5	<.10	<.10	.11
Body Weight	As in Muscle	37	.12	.11	.11
As in Muscle	Cd in Muscle	37	.68	.69	.26
As in Muscle	Zn in Muscle	37	.45	.44	.46
As in Muscle	Cu in Muscle	37	.13	<.10	<.10
As in Liver	Cd in Liver	5	<.10	<.10	.13
As in Liver	Zn in Liver	5	.21	.21	.21
As in Liver	Cu in Liver	5	<.10	<.10	<.10

(a)Using linear equation.

TABLE IV-13

COPPER IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO COPPER IN MUSCLE TISSUE OF CONTROL SAMPLES COLLECTED OFF-SITE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	W.S.P.	C	5.09	37	2.21	4.70	4	1.08	.344	73
<DL @ 1/2 DL:	W.S.P.	C	4.84	37	2.09	4.70	4	1.08	.126	89
<DL @ 1/2 DL, $X^{1/2}$:	W.S.P.	C	2.15	37	.450	2.16	4	.240	.018	98

[a] W.S.P. = Warm Springs Ponds.
[b] C = Control
[c] H_o = No Difference in means.

TABLE IV-14

COPPER IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO COPPER IN LIVER TISSUE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t value and % probability of erroneously rejecting H_o are presented for <DL reported the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	Mus.	L	5.09	37	2.21	45.94	5	33.14	-8.02	<1
<DL @ 1/2 DL:	Mus.	L	4.84	37	2.09	45.94	5	33.14	-8.08	<1
<DL @ 1/2 DL, $X^{1/2}$:	Mus.	L	2.15	37	.450	6.43	5	2.36	10.4	<1

(a)Mus. = Muscle.
(b)L = Liver.
(c)H_o= No Difference in means.

TABLE IV-15

COPPER IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY AGE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	A	J	5.58	13	2.46	4.82	24	2.07	.99	32
<DL @ 1/2 DL:	A	J	5.58	13	2.46	4.43	24	1.78	1.63	11
<DL @ 1/2 DL, $X^{1/2}$:	A	J	2.32	13	.478	2.06	24	.418	1.66	10

(a)A = Adult.
(b)J = Juvenile.
(c)H_o = No Difference in means.

TABLE IV-16

COPPER IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SEX.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	M	F	5.52	11	2.68	5.88	2	.900	.180	86
<DL @ 1/2 DL:	M	F	5.52	11	2.68	5.88	2	.900	.180	86
<DL @ 1/2 DL, $X^{1/2}$:	M	F	2.30	11	.517	2.42	2	.185	-.323	75
<DL @ DL:	M	Su	5.52	11	2.68	4.82	24	2.07	.850	40
<DL @ 1/2 DL:	M	Su	5.52	11	2.68	4.43	24	1.79	1.43	16
<DL @ 1/2 DL, $X^{1/2}$:	M	Su	2.30	11	.517	2.06	24	.418	1.42	16
<DL @ DL:	F	Su	5.88	2	.900	4.82	24	2.07	.708	49
<DL @ 1/2 DL:	F	Su	5.88	2	.900	4.43	24	1.79	1.11	27
<DL @ 1/2 DL, $X^{1/2}$:	F	Su	2.42	2	.185	2.06	24	.418	-1.17	25

(a)M = Male, F = Female.
(b)Su = Sex Unknown.
(c)H_o = No Difference in means.

TABLE IV-17

COPPER IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SUBFAMILY.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Ana.	Ayt.	4.90	17	2.40	5.92	14	2.00	-1.25	21
<DL @ 1/2 DL:	Ana.	Ayt.	4.90	17	2.40	5.25	14	1.86	-.436	67
<DL @ 1/2 DL, $X^{1/2}$:	Ana.	Ayt.	2.17	17	.472	2.25	14	.446	-.501	62
<DL @ DL:	Ana.	Ans.	4.90	17	2.40	3.69	6	1.36	1.17	25
<DL @ 1/2 DL:	Ana.	Ans.	4.90	17	2.40	3.69	6	1.36	1.17	25
<DL @ 1/2 DL, $X^{1/2}$:	Ana.	Ans.	2.17	17	.472	1.89	6	.344	1.30	21
<DL @ DL:	Ayt.	Ans.	5.92	14	2.00	3.69	6	1.36	2.48	2
<DL @ 1/2 DL:	Ayt.	Ans.	5.25	14	1.86	3.69	6	1.36	1.85	8
<DL @ 1/2 DL, $X^{1/2}$:	Ayt.	Ans.	2.25	14	.446	1.89	6	.344	-1.74	10

[a] Ana. = Anatinae, Ayt. = Aythyinae.
[b] Ans. = Anserinae.
[c] H_o = No Difference in means.

TABLE IV-18

CORRELATION TESTS FOR COPPER IN WARM SPRINGS PONDS WATERFOWL TISSUE.

Independent variables (x and y), number of pairs (N) and coefficient of determination (r^2) are presented for each test for <DL reported at the DL, for <DL reported at 1/2 the DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$.

X	Y	N	r^2 (a) <DL@ DL	<DL@ 1/2 DL	<DL@ 1/2 DL, Transformed
Body Weight	Cu in Liver	5	.32	.32	.32
Body Weight	Cu in Muscle	37	<.10	<.10	<.10
As in Muscle	Cu in Muscle	37	.14	<.10	<.10
Cd in Muscle	Cu in Muscle	37	.13	<.10	<.10
Zn in Muscle	Cu in Muscle	37	<.10	<.10	<.10
As in Liver	Cu in Liver	5	.92	.97	.87
Cd in Liver	Cu in Liver	5	<.10	<.10	<.10
Zn in Liver	Cu in Liver	5	.23	.23	.31

(a)Using linear equation.

TABLE IV-19

ZINC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO ZINC IN CONTROL WATERFOWL MUSCLE TISSUE COLLECTED OFF-SITE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	W.S.P.	C	13.32	37	3.93	10.9	4	3.05	1.19	24
<DL @ 1/2 DL:	W.S.P.	C	13.32	37	3.93	10.9	4	3.05	1.19	24
<DL @ 1/2 DL, $X^{1/2}$:	W.S.P.	C	3.61	37	.525	3.28	4	.450	-1.22	23

(a)W.S.P. = Warm Springs Ponds.
(b)C = Control.
(c)H_o = No Difference in means.

TABLE IV-20

ZINC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED TO ZINC IN LIVER TISSUE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y) t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x[a]	y[b]	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o[c]
<DL @ DL:	Mus.	L	13.32	37	3.93	55.98	5	28.79	-9.10	<1
<DL @ 1/2 DL:	Mus.	L	13.32	37	3.93	55.98	5	28.79	-9.10	<1
<DL @ 1/2 DL, $X^{1/2}$:	Mus.	L	3.61	37	.525	7.31	5	1.77	10.34	<1

(a) Mus. = Muscle.
(b) L = Liver.
(c) H_o = No Difference in means.

TABLE IV-21

ZINC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY AGE.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	A	J	10.75	13	2.56	14.71	24	3.87	-3.31	2
<DL @ 1/2 DL:	A	J	10.75	13	2.56	14.71	24	3.87	-3.31	2
<DL @ 1/2 DL, $X^{1/2}$	A	J	3.86	13	.376	3.80	24	.500	-3.43	2

(a)A = Adult.
(b)J = Juvenile.
(c)H_o = No Difference in means.

TABLE IV-22

ZINC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SEX.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	M	F	10.84	11	2.76	10.28	2	1.29	.270	79
<DL @ 1/2 DL:	M	F	10.84	11	2.76	10.28	2	1.29	.270	79
<DL @ 1/2 DL, $X^{1/2}$:	M	F	3.27	11	.405	3.20	2	.202	.218	83
<DL @ DL:	M	Su	10.84	11	2.76	14.71	24	3.87	-2.98	5
<DL @ 1/2 DL:	M	Su	10.84	11	2.76	14.71	24	3.87	-2.98	5
<DL @ 1/2 DL, $X^{1/2}$:	M	Su	3.27	11	.405	3.80	24	.500	-3.10	4
<DL @ DL:	F	Su	10.28	2	1.29	14.71	24	3.87	-1.58	13
<DL @ 1/2 DL:	F	Su	10.28	2	1.29	14.71	24	3.87	-1.58	13
<DL @ 1/2 DL, $X^{1/2}$:	F	Su	3.20	2	.202	3.80	24	.500	-1.66	11

(a) M = Male, F = Female.
(b) Su = Sex Unknown.
(c) Ho = No Difference in means.

TABLE IV-23

ZINC IN WARM SPRINGS PONDS WATERFOWL MUSCLE TISSUE COMPARED BY SUBFAMILY.

Means ($\bar{x}$, $\bar{y}$), Number of Samples (N_x, N_y), Standard Deviations (S_x, S_y), t values, and % probability of erroneously rejecting H_o are presented for <DL reported at the DL, for <DL reported at 1/2 DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$. All values in µg/g.

	x(a)	y(b)	$\bar{x}$	N_x	S_x	$\bar{y}$	N_y	S_y	t	% Probability of Erroneously Rejecting H_o(c)
<DL @ DL:	Ana.	Ayt.	11.63	17	3.24	14.87	14	4.53	2.32	3
<DL @ 1/2 DL:	Ana.	Ayt.	11.64	17	3.24	14.87	14	4.53	2.31	3
<DL @ 1/2 DL, $X^{1/2}$:	Ana.	Ayt.	3.38	17	.457	3.82	14	.582	-2.32	3
<DL @ DL:	Ana.	Ans.	11.63	17	3.24	14.48	6	2.46	-1.95	6
<DL @ 1/2 DL:	Ana.	Ans.	11.64	17	3.24	14.48	6	2.46	-1.95	6
<DL @ 1/2 DL, $X^{1/2}$:	Ana.	Ans.	3.38	17	.457	3.79	6	.326	-2.02	6
<DL @ DL:	Ayt.	Ans.	14.87	14	4.53	14.48	6	2.46	.197	84
<DL @ 1/2 DL:	Ayt.	Ans.	14.87	14	4.53	14.48	6	2.46	.197	84
<DL @ 1/2 DL, $X^{1/2}$:	Ayt.	Ans.	3.82	14	.582	3.79	6	.326	-.085	93

(a)Ana. = Anatinae, Ayt. = Aythyinae.
(b)Ans. = Anserinae.
(c)H_o = No Difference in means.

TABLE IV-24

CORRELATION TESTS FOR ZINC IN WARM SPRINGS PONDS WATERFOWL TISSUE.

Independent variables (x and y) number of pairs (N) and coefficient of determination (r^2) are presented for each test for <DL reported at the DL, for <DL reported at 1/2 the DL, and for <DL reported at 1/2 DL and transformed by $X^{1/2}$.

X	Y	N	r^2 (a) <DL@ DL	<DL@ 1/2 DL	<DL@ 1/2 DL, Transformed
Body Weight	Zn in Liver	5	.41	.41	.42
Body Weight	Zn in Muscle	37	<.10	<.10	<.10
As in Muscle	Zn in Muscle	37	.38	.39	.30
Cd in Muscle	Zn in Muscle	37	.45	.44	.46
Zn in Muscle	Cu in Muscle	37	<.10	<.10	<.10
As in Liver	Zn in Liver	5	<.10	.18	.14
Cd in Liver	Zn in Liver	5	.21	.21	.21
Zn in Liver	Cu in Liver	5	.23	.23	.31

(a) Using linear equation.